New Technology-based firms - from conceptualization to application

Dina Isabel Correia Pelicano da Cunha

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Supervisors:

Sandra Tavares Silva

Aurora A.C. Teixeira

Short Bio

Dina Isabel Correia Pelicano da Cunha was born in Porto, on October 14, 1967.

She started her undergraduate studies at the *Faculdade de Economia da Universidade do Porto* in 1985. In 1991 she received her Economy degree.

During the last 20 years her career was related with venture capital investments, start-ups' incubation and business innovation.

She initiated post graduate studies in 2009 and is presently enrolled in the Master in Economics and Innovation Management at *Faculdade de Economia da Universidade do Porto*, with the dissertation entitled "New Technology-based firms - from conceptualization to application".

Acknowledgements

"You see things, and you say 'Why?'.
But I dream things that never were, and I say 'Why not?'."
(George Bernard Shaw; Back to Methuselah, 1921, Part I, Act I)

Deciding to take the master degree in Economics and Innovation Management meant being able of changing my own life, assuming a new perspective and a new understanding. To all my Professors, colleagues and friends, *THANK YOU!* for what you taught me, the mutual exchange of experiences, and the friendship received.

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To all and everyone that has been part of my life and are in my heart, also a word of acknowledgement.

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Abstract

New Technology Based Firms (NTBFs) have gained increasing economic relevance, supported by the recognition that they play an important role in national economies in the appearance of both new, high technology products and of new and emerging industries.

Despite their economic importance, a number of alternative definitions of NTBFs are referred in the literature, many of them adjusted to the aim of the study or the sample under observation. Such lack of conceptualization reflects the variety of perspectives and interests of researchers, and led to the need of a coherent framework for the study of NTBFs. No agreement exists so far on which are the key characteristics of NTBF. This lack of consensus in the conceptualization of NTBFs does not permit an adequate applicability of the concept or a comparison throughout the different existing studies.

This is the motivation and the challenge underlying the present dissertation. Firstly, we review and systematize the existing definitions for NTBFs. This endeavor aims to sustain a new and/or a revised definition of NTBFs. Then, we apply the proposed definition to a set of small, high tech firms, the so called 'academic spin offs' (ASOs) incubated in the Universidade do Porto (UP), trying to assess the extent to which this group of firms might be, in fact, classified as NTBFs.

Based on a sample of 30 firms, it was possible to conclude that, contrary to common wisdom, not all ASOs are NTBFs. Additionally, the ASOs classified as NTBFs, according to our criteria, distinguish significantly from the other ASOs, presenting a higher level of capital invested, higher R&D and internationalization intensity, and founding teams with higher presence of individuals with management capabilities.

Keywords: New technology-based firms; Academic Spin-offs; Portugal

JEL-Codes: O30; O32

Resumo

As Novas Empresas de Base Tecnológica (normalmente conhecidas como NTBFs) têm vindo a reforçar a sua preponderância económica, pelo reconhecimento crescente da sua função nas economias nacionais, com o aparecimento de novos produtos *high-tech* e novas indústrias emergentes.

Apesar da sua importância económica, um número abrangente de definições alternativas são referidas na literatura, muitas das quais ajustadas ao propósito da investigação ou à amostra em análise. Esta falta de sistematização conceptual, justificada por um número alargado de características associadas a esta categoria específica de empresas, reflete uma variedade de perspetivas e interesses de investigação distintos, conduzindo à necessidade de apresentar uma estrutura coerente para o estudo das NTBFs. Esta falta de consenso na conceptualização, não permite uma aplicação adequada do conceito de NTBF ou uma comparação sistematizada nos diferentes estudos.

Esta foi a motivação e o desafio que justificaram a dissertação agora apresentada. Primeiro foram revistas e sistematizadas as definições existentes para o conceito de NTBF, tendo o esforço realizado, permitido apresentar uma definição abrangente que foi posteriormente aplicada a um grupo de pequenas empresas *high-tech*, normalmente chamadas de 'spin-offs académicos', na tentativa de determinar até que ponto este grupo de empresas poderia ser classificado como NTBF.

Tendo como base uma amostra de 30 empresas, foi possível concluir, ao contrário do entendimento comum, de que nem todos os 'spin-offs académicos' são NTBFs.

Adicionalmente, o grupo de 'spin-offs académicos' classificado como NTBFs, de acordo com a aplicação dos critérios identificados, distingue-se do outro grupo de ‘spin-offs’, apresentando maior investimento no capital social das empresas, I&D superior e maior intensidade exportadora, com equipas fundadoras onde a presença de indivíduos com capacidades de gestão é também fator diferenciador.

Palavras-chave: New Technology-Based Firms (NTBFs), Portugal; Spin-offs
Códigos JEL: O30; O32

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Acronyms

ASOs	Academic Spin-offs
CEO	Chief Executive Office
CSOs	Corporate Spin-offs
ESOs	Entrepreneurial Spin-offs
ICT	Information and Communication Technology
ISIC	International Standard Industrial Classification
KBV	Knowledge-based view
NTBFs	New Technology-based firms
OECD	Organization for Economic Co-Operation and Development
R&D	Research & Development
SMEs	Small and Medium Enterprises
TBF	Technology-based firm
TBNF	Technology-Based New Firm
UP	Universidade of Porto
UPTEC	U. Porto Science and Technology Park
USA	United States of America
USOs	University Spin-offs

1. Introduction

New Technology Based Firms (NTBFs) have gained increasing economic relevance (Cooper, 1971; Autio, 1997a; Bollinger et al., 1983; Storey and Tether 1998a; Grinstein and Goldman, 2006), supported by the recognition that they play an important role in economies' competitiveness through the appearance of both new, high technology products and of new and emerging industries (Cooper, 1971; Rothwell, 1989; Autio, 1997a).

Associated with the NTBFs' importance and the emergence of new industries, some authors (e.g., Rothwell, 1989) refer the Fairchild semi-conductor case-study that has exhibited growing performance with sales from $0.5 million in 1960 up to $520 million in 1978 and the appearance of several NTBFs as a group with significant economic impact. Another reference in the literature is the case of the computer aided design (CAD) industry and the Computervision leadership in the USA during the 1980s (Kaplinsky, 1981). Later, Slater (1987) studied some then considered 'NTBFs' like DEC, Hewlett-Packard and Apple Computer and the biotechnology industry pioneer Genentech (Autio, 1997a). This link between new technologies and new industries reinforced the interest in NTBFs (Dosi, 1984; Rothwell and Zegveld, 1985).

Despite the economic importance of NTBFs, many authors (e.g., Storey and Tether, 1998a; Delapierre et al., 1998; Elorz, 2003; Grinstein and Goldman, 2006) agree that the NTBF definition is not simple and does not reflect homogeneous economic realities, with distinct authors proposing distinct concepts.

The first definition found in the literature, a starting point in the conceptualization of NBTFs, is described by Cooper (1971: 3): "a firm that emphasizes research and development or that places major emphasis on exploiting new technical knowledge".

Some few years later the Arthur D. Little Group (1977) associated NTBFs with an independently owned business established for not more than 25 years and based on the exploitation of an invention or technological innovation implying substantial technological risks. Later, Shearman and Burrell (1988) referenced the term as "new independent firms which are developing new industries" (Storey and Tether, 1998a:

934), whereas Butchart (1987) identified NTBFs as small and medium-sized firms operating in high technology sectors.

Such earlier definitions of NTBFs reflect the difficulty in its conceptualization. Indeed, performing a review of studies on NTBFs spanning 16 countries in Europe, Storey and Tether (1998a) confirm that those studies were based on high-tech SMEs rather than 'NTBFs', and in technology-intensive sectors instead of new and emerging industries. According to the same authors, those studies revealed other weaknesses, including the fact that they embraced both younger and older firms, without providing any information about the independently owned status of firms.

The use of distinct definitions continues nowadays, with researchers adjusting the concept to the aim of their study or the sample under observation. Specifically, Laranja and Fontes (1998) and Fontes and Coombs (2001) explicitly devise NTBFs definitions for the purpose of their studies, with the latter study defining NTBFs, in the context of less advanced countries, as "young independent firms involved in the development and/or diffusion of new technologies" (Fontes and Coombs, 2001: 83). This understanding about the NTBFs phenomenon in less advanced countries breaks the direct linkage between new technologies and new industries and proposes an important role for NTBFs as key actors in the diffusion of technological knowledge developed in more advanced economies (Laranja and Fontes, 1998; Fontes and Coombs, 2001).

In sum, although NTBF is a common term in the economic literature and despite the considerable research produced since the 1960s, its definition remains unclear and its application strongly differs between authors, time and space (Autio, 1997a; Bollinger et al, 1983; Storey and Tether, 1998a; Laranja and Fontes, 1998; Fontes and Coombs, 2001). This lack of consensus in the conceptualization of NTBFs prevents adequate empirical application and thus fruitful comparison of studies in time and space.

This is the motivation and the challenge underlying the present dissertation. Firstly, we review and systematize the existing definitions for NTBFs, which could sustain a new or an enlarged/revised definition. Then, we will apply the definition proposed to a set of firms, small and high tech firms, the so called 'academic spin offs', trying to assess the extent to which this group of firms might be or not categorized as NTBFs. More

specifically, which are the criteria that academic spin offs comply or not comply as regarding to be categorized as NTBFs.

The study is structured as follows. In Chapter 1 an overview of the relevant literature on the concept of NBTFs is presented, and a new/revised concept able to be operationalized is put forward, which includes the main characteristics of NTBFs identified in the literature. Chapter 2 details the methodological considerations, namely the proxies for the criteria of NTBFs classification applying a bibliometric exercise. Then, Chapter 3 focus on the description of the target population of firms - the academic spin-offs and the methodology concerning our sample is presented. The main results of the empirical analysis are discussed in Chapter 4. Finally, in Conclusions the main contributions and limitations of the work, as well as suggestions for additional research on NBTFs, are put forward.

2. Towards a definition of NBTFs: a qualitative and quantitative review of the literature

2.1. The vagueness associated with the concept of NTBFs

The sustainability of economic growth is important to each individual economy and this is the main issue in the literature that discusses the importance of NTBFs (Cooper 1971; Rothwell, 1989; Autio, 1997a; Storey and Tether 1998a; Hogan and Hutson, 2005; Grinstein and Goldman, 2006; Robb and Coleman, 2010). As Freeman (1993: 11) highlights "economic growth is not merely accompanied by fast growing new industries and the expansion of such industries; it primarily depends on that expansion". According to this understanding, the achievement and maintenance of sustainable rates of growth is directly linked to the capacity of firms and other national actors to innovate and develop new technologies, new products and new industries (Rickne and Jacobsson, 1999; Buganza et al., 2010), assuming that technological change is an important key factor in the explanation of economic growth (Teixeira, 2012).

The issue here is that when we refer to "New Technology-Based Firms", we often do not know exactly what we are really meaning (Autio, 1997a; Storey and Tether 1998a). Frequently, a variety of different concepts are used when we are analyzing new or small firms with strong technological focus (Rickne and Jacobsson, 1999), for example, new technology-based firms (Autio, 1997a; Laranja and Fontes, 1998; Fontes and Coombs, 2001), technology-based small and medium firms (Mason and Harrison, 1994; Dahlstrand, 1999), small technology-based firms (Meyer and Roberts, 1986; Forrest, 1990; Klofsten and Jones-Evans, 1996), technology-intensive small firms (Keeble et al., 1998), or high technology SMEs (Oakey, 1991).

As there are different concepts used in the literature, this fact induces confusion, denoting the absence of an integrated and coherent theoretical framework. This implies that when analyzing conclusions from different studies, generalizations are impossible, as the samples studied are not directly comparable (Storey and Tether, 1998a).

Another observed fact is that many authors adjust the concept of NTBFs to the sample in analysis (Storey and Tether, 1998a; Laranja and Fontes, 1998; Fontes and Coombs, 1996, 2001; Rickne and Jacobsson, 1999).

In reviewing the literature on the concept of NTBFs, we were able to confirm little cross-referencing indicating that none of the definitions proposed succeeded in being commonly accepted by other researchers.

Despite the lack of consensus in the concept of NTBFs, during the last 50 years, there was a significant evolution, with the emergence of increasingly complex definitions.

One first important commonality on all the surveyed studies (cf. Table 1) refers to the importance of technology in this type of firms (Cooper, 1971; Little, 1977; Autio, 1994; Fontes and Coombs, 1996, 2001; Laranja and Fontes, 1998; Chamanski and Waag, 2001; Candi and Saemundsson, 2008), or the exploitation of new technical knowledge (Cooper, 1971; Little, 1977). In their empirical studies on NTBFs, Autio (1994) and Fontes and Coombs (2001) confirm the association of this type of firms to the development and exploitation of advanced technological knowledge.

It is important to remark that the term 'new' may have distinct interpretations (see Table 1). Some authors refer and apply the term to the *technology newness* (Fontes and Coombs, 1996, 2001), or simply adjust it to the *youth of the firm* (Rickne and Jacobsson, 1999). Cooper (1971), in his conceptual proposal, suggests the *newness of the technical exploitation*, whereas Little (1977) clearly refers the *youth of the firm*. This potential duality of interpretations is clearly posited by Delaney (1993: 206), who suggests that "new technologies may be expected to be brought to the market through new firms". Autio (2000), confirming the ambiguity of the concept, adopts and suggests an alternative term, 'technology-based new firm' (TBNF), in an attempt to clarify this point (Hogan and Hutson, 2006).

A large part of the studies (cf. Table 1) use the term 'new' simultaneously for *youth of the firm* and for referring *technological newness*. However, when analyzing some conceptual proposals in greater depth, we uncover an additional meaning for ‘new’ in NTFBs - the emergence of ‘new industries’ (Shearman and Burrell, 1988). Thus, the conceptualization of NTBFs may include not just the *newness of the firm* and the *technology* but also of the *industry*.

Table 1: NTBFs definitions

Studies	Definitions	Key dimensions of the definition			
Cooper (1971)	Firm that emphasizes research and development or that places major emphasis on exploiting new technical knowledge.	New knowledge			
Autio (1994)	Business idea of the firm is essentially based on exploiting advanced technological knowledge developed or acquired in a source of technology.			Technology intensive	
Little (1977)	Independent owned business established for not more than 25 years and based on the exploitation of an invention or technological innovation which implies substantial technological risks.		Independent		
Bollinger et al (1983)	New and independent firm associated with a small group of founders highly motivated to explore a technically innovative idea.	New firm			
Fontes and Coombs (1996, 2001)	New/young and independent firms involved in the development and/or application of new technologies.		Independent		
Shearman and Burrell (1988)	New independent firms which are developing new industries.				
Coeurderoy and Murray (2008)	New and independent high-tech firms formed within the last 10 years.				
Candi and Saemundsson (2008)	New independent firms that develop new products and services based on the technical knowledge of their founders.				
Chamanski and Waag (2001)	New firms developing and serving knowledge and technology intensive products or services.			Technology intensive	
Candi and Saemundsson (2011)	New business entities that develop new offerings based on the knowledge and skills embodied in engineering and the natural sciences.				
Maine et al. (2010)	Young and initially small firms operating in research and development (R&D) intensive sectors.				Small
Klofsten (1994)	Competitive edge derives from engineering know-how of people who work in the firm and its subsequent transformation into products or services for a market.				
Rickne and Jacobsson (1996, 1999)	Firm whose strength and competitive edge derives from the know-how within natural science, engineering or medicine of the people that work in the firm and its subsequent transformation into products or services for a market.				
Butchart (1987)	Small and medium-sized firms operating in high technology sectors.				Small
Oakey et al. (1988)	Small firms with a higher inherent innovative potential than large firms and small firms in general.				

The interpretation of *newness* integrates different perspectives and constitutes an important discussion on the development of NTBFs in less advanced *versus* technologically advanced economies (Fontes and Coombs, 1996, 2001; Laranja and Fontes, 1998), breaking the 'traditional' association of NTBFs with the introduction of new technologies and new industries, and being more related to technological acquisition, transformation and diffusion. The association between new technologies and new industries has been inflated in Europe and even in the USA (Oakey, 1994), being this linkage restricted in geography, sectors and time-specific contexts.

Another key characteristic of NTBFs (cf. Table 1) is the *independence* of the firm. Accordingly, in a NTBF the capital must be mainly owned by the entrepreneurial team (Little, 1977; Shearman and Burrell, 1988; Fontes and Coombs, 1996, 2001). This characteristic has its source in the seminal work of Roberts and Weiner (1966), in their study of the spin-offs in the Route 128, clearly identifying small nucleus of people as NTBFs founders, and proving that the firm was totally independent, in that it was not a part (or subsidiary) of a large firm (Bollinger et al., 1983). In that sense, to be independent means that the majority of the social capital of these firms still belongs to the entrepreneurial team (Rickne and Jacobsson, 1999).

We can also identify the association of NFBFs with their size. Some authors, such as Butchart (1987), Oakey et al. (1988) and, more recently, Maine et al. (2010), clearly define NTBFs as small firms.

In sum, four central aspects are to be considered when defining NTBFs: technology newness and new industry emergence, age of the firm, dimension of the firm, and finally independence.

Adopting more encompassing definitions, some authors identified characteristics related to the high level of education and know-how associated with NTBFs founders. Laranja and Fontes (1998: 1026) specifically refer "a small venture team with a strong educational background in science and engineering", and Rickne and Jacobsson (1999: 203) assume that the "NTBFs competitive edge derives from the know-how within natural science, engineering or medicine of the people who work in the firm". Indeed, some recent empirical studies emphasise this aspect, arguing that specific human capital is more important for the performance of NTBFs in relation to other aspects, and that

the performance of a NTBF can improve through the combination of heterogeneous but complementary skills (Colombo et al., 2004; Colombo and Grilli, 2005b; Ganotakis, 2010).

This initial overview about the concept of NTBF has confirmed the difficulty on a unique and universal interpretation, and has indicated that the construction of the concept encompasses different dimensions. In order to get a clearer and quantitative view on this issue, we implemented a bibliographic exercise, which is detailed in the next section.

2.2. A quantitative/bibliometric account of the concept of NTBF

We develop a quantitative review on the characteristics of NTBFs, supported by the search and gathering of related papers published in economic journals. The search was based on the bibliographic database SciVerse Scopus (from Elsevier), restricted to the subject area 'Social sciences and Humanities'.[1]

The selection criterion was the expression 'New technology-based firms' in the fields 'Article title, abstract, keywords' and with no restrictions in terms of data range, for articles or reviews. This search resulted in a set of 134 papers, 118 articles and 16 reviews, over a period of 30 years (from 1981 to 2011). After reviewing the selected articles, we found 25 records with only the abstract and no public access to the paper. In addition, for 34 articles we found that they did not propose a NTBF definition or the description of its fundamental characteristics. We thus excluded these articles from the analysis. In the end, as our basis of analysis we had 75 articles (Figure 1).

[1] SCOPUS is an Electronic database considered the largest abstract and citation database of peer-reviewed literature and quality web resources. It contains nearly 19.500 titles from 5.000 publishers worldwide. (Source: http://www.info.sciverse.com/scopus/about, accessed on 10 September 2011).

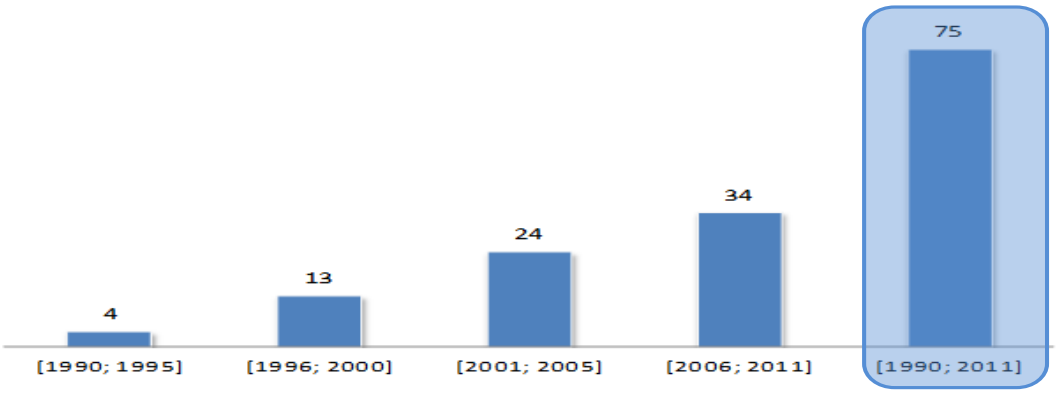

Figure 1: Number of articles analyzed on NTBFs definition, 1990-2011

By comparing the number of analyzed NTBFs papers with all the papers gathered from Scopus, over the same time period, based on the search key 'innovation', we conclude that NTBFs studies observed a significant increase in the period from 1996 up to 2000. In fact, whilst total publications on the general subject 'innovation' increased by 191%, publications concerning NBTFs increased by 225%. However, since 2001 this research topic lost momentum when compared with total records on 'innovation' (see Table 2).

Table 2: Evolution of bibliographic Database SciVerse Scopus Publications

Periods	NTBFs (*)	Average Growth	Innovation	Average Growth
1990-1995	4	-	2.275	-
1996-2000	13	225%	6.610	191%
2001-2005	24	85%	10.953	66%
2006-2011	34	42%	20.214	85%
All_Periods	75	-	40.052	-

(*) We consider NTBFs publications until 30_Sep_2011.

The bibliometric exercise allowed to assess the relevance over time, and for the whole period considered, of the five key dimensions, which, according to the literature surveyed (Section 2.1), are directly associated with NTBFs definitions: 1) technology newness and industry emergence; 2) youth of the firm; 3) dimension of the firm; 4) independence of the firm; and 5) founding team's capabilities.

1) Technology newness and industry emergence

Several definitions of NTBFs focus on the "exploitation of new technical knowledge" (Cooper, 1971: 5), or "exploiting advanced technological knowledge" (Autio and Yli-Renko, 1998a: 975) or mention the "development and/or diffusion of new technologies"

(Fontes and Coombs, 1995: 499; 2001: 83). Thus, one might argue that the NTBFs dynamics is directly linked to technology. Nevertheless, there is a problem in how to define 'technology-based' firms.

Commonly, authors define a technology-based firm as a firm that depends on technology to survive and grow. This perspective, however, does not mean that the technology has to be new (Dahlstrand, 2007); the key factor is that the firm depends on technology.

Some authors have been using the concept 'high-technology' in order to reflect technological newness. The operationalization of the concept, following Butchard's proposal (1987) involves measures of resource inputs to high technology, like investment in Research and Development (R&D) and proportion of employees in R&D (Löfsten and Lindelöf, 2001, 2003, 2005a, 2005b; Lindelöf and Löfsten, 2002, 2004, 2006; Aaboen et al., 2006; Ganotakis and Love, 2011).

The most frequent indicator on high-tech resorts to OECD classification (cf. Table 3). Accordingly, industries are classified as high-tech when the R&D intensity ratio (R&D expenditures by value-added, turn-over or sales) is above 5% (Godin, 2004).

Table 3: OECD taxonomical categories

CATEGORIES	R&D intensity (R&D expenditures/value added)
Low-tech industries	0 to 0.9%
Medium low-tech industries	0.9% to 3%
Medium high-tech industries	3% to 5%
High-tech industries	More than 5%

Source: Smith (2005).

The analysis of articles confirms a growing association between NTBFs and 'high-tech' sectors. Although some authors consider simplistic the classification of sectors in 'high' and 'low' tech, failing to capture the dynamics of innovation which are relevant in sectors other than 'high tech' (Laestadius, 1998; Dahlstrand and Jacobsson, 2003), this association to NTBFs has gained relevance through the 2000s, with almost three quarters of the papers published in this period mentioning this as key identifying dimension of NTBFs.

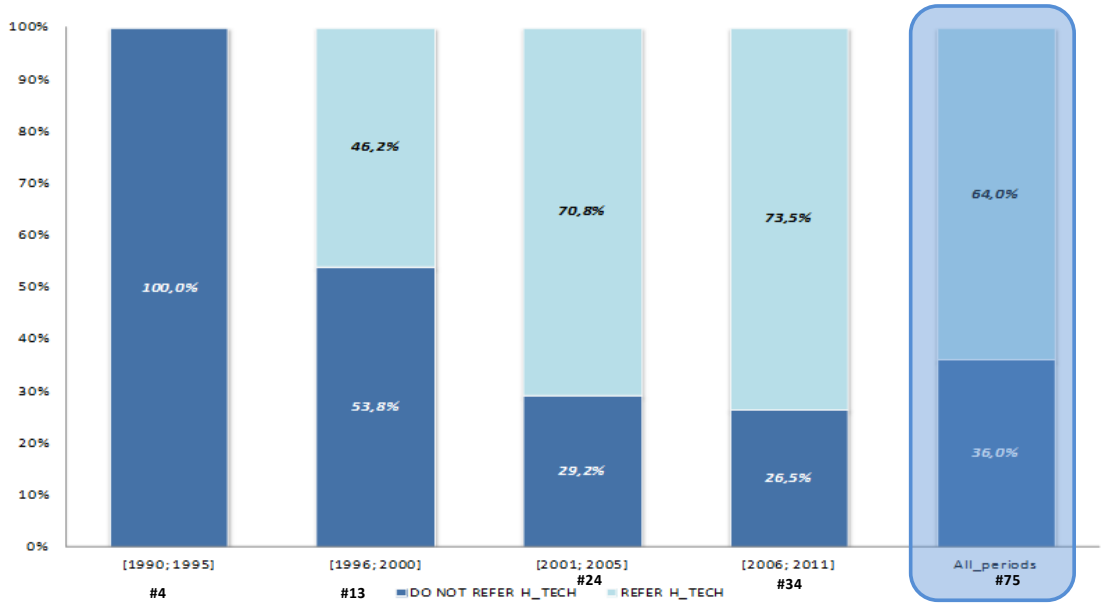

Figure 2: Distribution (%) of articles by the 'high-tech' criterion, 1990-2011

As observed in Figure 2, 'high-tech' is increasingly used as a criterion for characterizing NTBFs. In the period 1990-1995, no article expressly associated NTBFs to high-tech intensity, whereas in the 2006-2011 period this association represents 73.5% of the analyzed papers.

Another operationalization of 'technology-based' characteristic of NTBFs is the definition by sector, materialized by aggregating the samples into manufacturing and/or services.

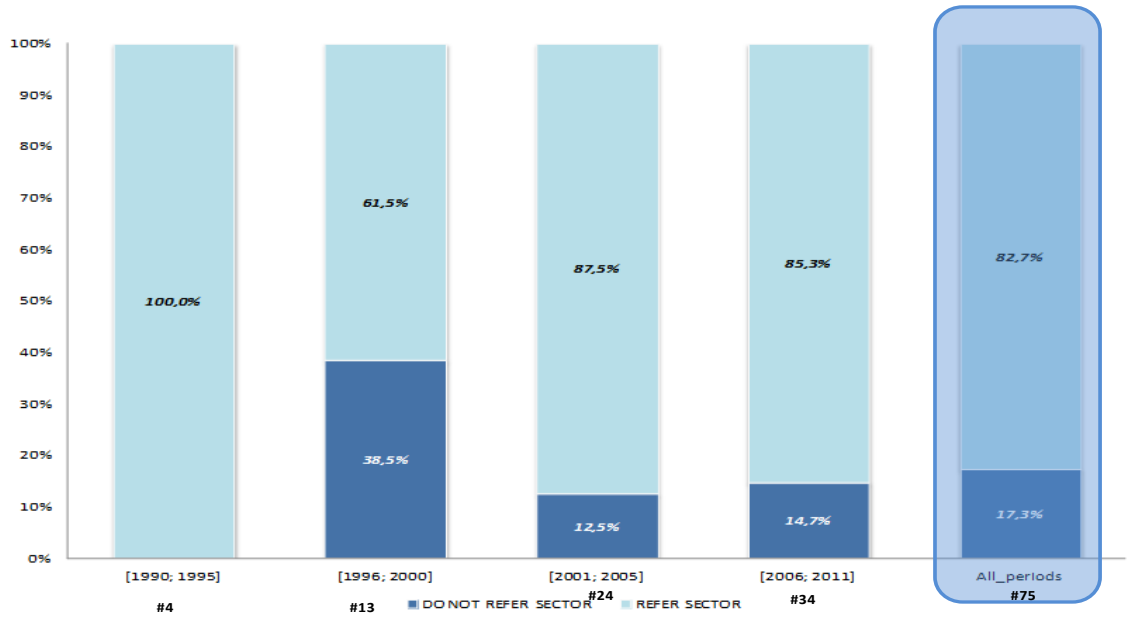

Figure 3: Distribution (%) of articles by the 'Sector definition' criterion, 1990-2011

Excluding the initial period which encompasses only 4 papers, in the subsequent periods the percentage of articles that associate NTBFs to a sectoral categorization of activities is quite high, observing a quite stable figure (around 85%).

Analyzing Figures 2 and 3 we can argue that the 'high-tech' criterion is linked to the 'sector categorization'. The analysis confirms that period after period several articles relate and link these two dimensions for the study and selection of NTBFs samples.

The first exercise, concerning sectors' identification comprised the analysis of the number of publications that identified manufacturing or services (cf. Table 4). Globally 'manufacturing' and 'services' revealed 56 and 47 publications, respectively.

Table 4: Evolution in terms of manufacturing and services identification

Sector Identification	[1990; 1995]	[1996; 2000]	[2001; 2005]	[2006; 2011]	All Periods
Manufacturing	4	8	19	25	56
Services	0	6	17	24	47

Then we have identified and systematized the authors' choices in terms of sector criterion, quantifying those articles choosing manufacturing and services economic activities (cf. Figures 4 and 5).

Some authors, such as Shearman and Burrell (1988), relate NTBFs with new industries. This relation seems too simplistic, in the sense that it can only be used for emerging industries (like medical laser industry) but it does not consider new firms operating in consolidated industries.

Analyzing this particular issue, our bibliometric revision confirms that authors identify a wide range of sectors normally considered as 'high-tech' (and 'medium high-tech'), like 'Pharmaceuticals', 'Aerospace', 'ICT' industries',[2] 'Electrical Machinery and Apparatus', 'Robotics and Process Automation', and 'Chemistry'.

[2] The ICT classification includes a large number of economic activities, according to the Frascatti Manual (2002), which describes a list of industries both in manufacturing and related services belonging to the Information and Communication Technology Sector in ISIC Rev.3: for example, computer, electronic components, telecommunications equipment, optical, medical and electronic instruments.

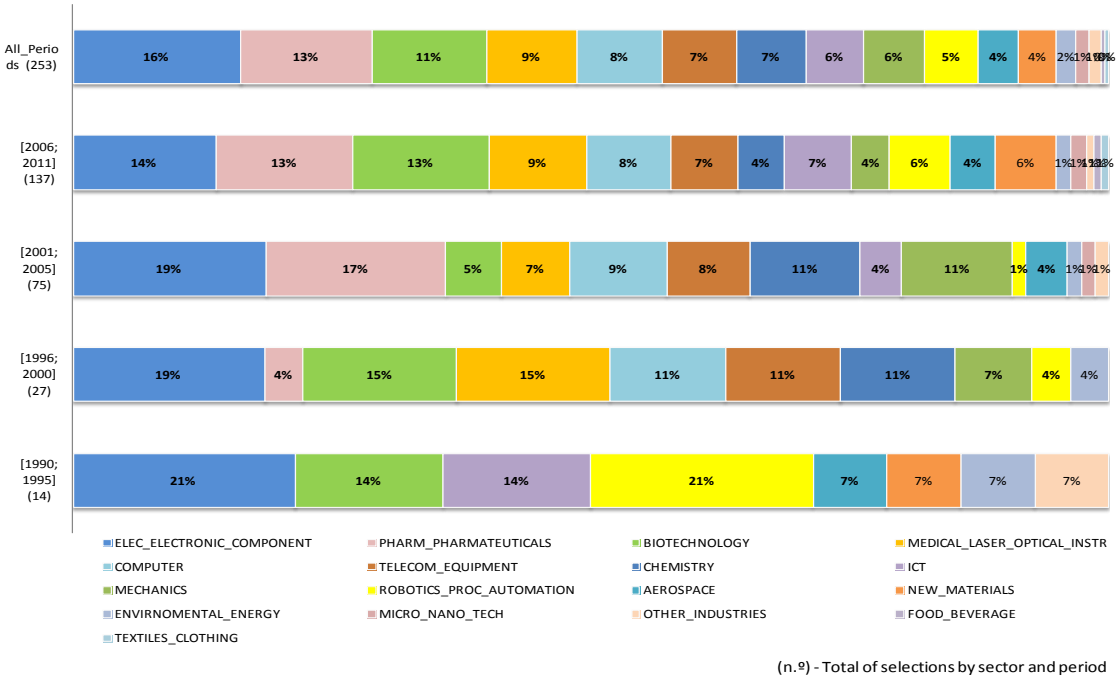

Figure 4: Distribution (%) of articles by manufacturing sectors, 1990-2011

Over the analyzed periods, we could aggregate the manufacturing sectors into two distinct groups. The first group gathers the most frequently identified industries for the overall period, 1990-2011, like 'Electric and Electronics', 'Pharmaceutical and Biotechnology', 'Medical and Optical instrumentation', 'Computer' or 'Telecommunications'. This group seems to be the most consensual in the NTBFs authors' studies, in the last fifteen years, although their weight is decreasing. Specifically, the 'Electric and Electronic Components' sector corresponded to 19% in 1996-2000and to 14%, in 2006-2011, being considered in 41 studies during the total period. 'Biotechnology' encompassed 15% in the 1996-2000 period, down to 13% in the last period of analysis, being associated globally with 28 studies.

The 'Pharmacology and Pharmaceutical', 'Medical, laser and optical instruments', 'Computer', and 'Telecommunications equipments' sectors, present stable figures around, respectively 13%, 9%, 8% and 7%.

Our bibliometric exercise permitted to identify a second group of NTBFs associated with more recent industries, such as 'Micro and Nanotechnologies', and 'Environment and Energy'. However, in the last period of analysis, some authors also associated

NTBFs with firms that introduce new technologies in sectors with less high-tech sectors such as 'Textiles and Clothing' or 'Food and Beverages'.

Hence, the industries' distribution over the analyzed periods confirms that NTBFs are important not only for the introduction of new technologies and new industries but also for technological acquisition, transformation and diffusion, in the sense that authors identify NTBFs in 'new' sectors but also, in 'old' sectors, confirming several conclusions from the relevant literature (Fontes and Coombs, 1995, 2001; Laranja and Fontes, 1998).

It is interesting to note that during the five years period in analysis, the number of sectors identified as being associated with the NBTFs label, increased continually. In the 1990-1996 period, we identified NTBFs samples associated with 8 different sectors whereas in the 2006-2011 period 17 distinct sectors were mentioned.

The literature commonly associate NTBFs with firms operating in high-tech sectors, which is in line with Butchard's conceptualization proposed in 1987 (see Table 1), being those not only in manufacturing but also in services. In quantitative terms, the analysis of articles confirms that NTBFs samples from high-tech services started to be studied in the 1996-2000 period. NTBFs operating in the 'Internet based services' and 'Multimedia' sectors started to be studied in the 2000s (cf. Figure 5).

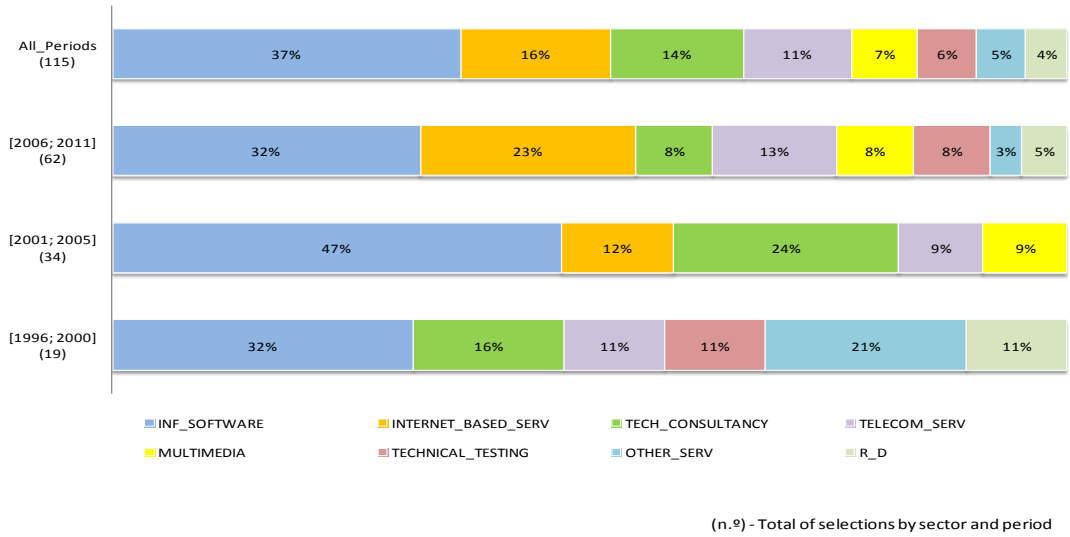

Figure 5: Distribution (%) of articles on NTBFs in services, 1996-2011

Although our analysis confirms ups and downs in the selection of some activities through the periods, 'Information and Software' presented a relative weight of 32% in the 2006-2011, whereas 'Telecommunications services' reached 13%. Although 'Information and Software' is the most cited sector in the high-tech services (42 studies identified NTBFs operating in this area), 'Internet based Services' registers an impressive second position (18 studies, globally), with 23% of the total published papers in the 2006-2011 period.

2) Youth of the Firms

The quantitative analysis of our database reveals that the 'Youth of the firms' seems to be the most important one in what concerns the operationalization of NTBFs concept.

Indeed, almost all papers in our database refer the birth period in their definition of NTBF. Only twelve papers (out of the 75) do not explicitly define the birth period or age of the firm. Nevertheless, although the birth/age of the firm is the most present dimension in the studies surveyed, the age interval considered in each study differs – see Figure 6.

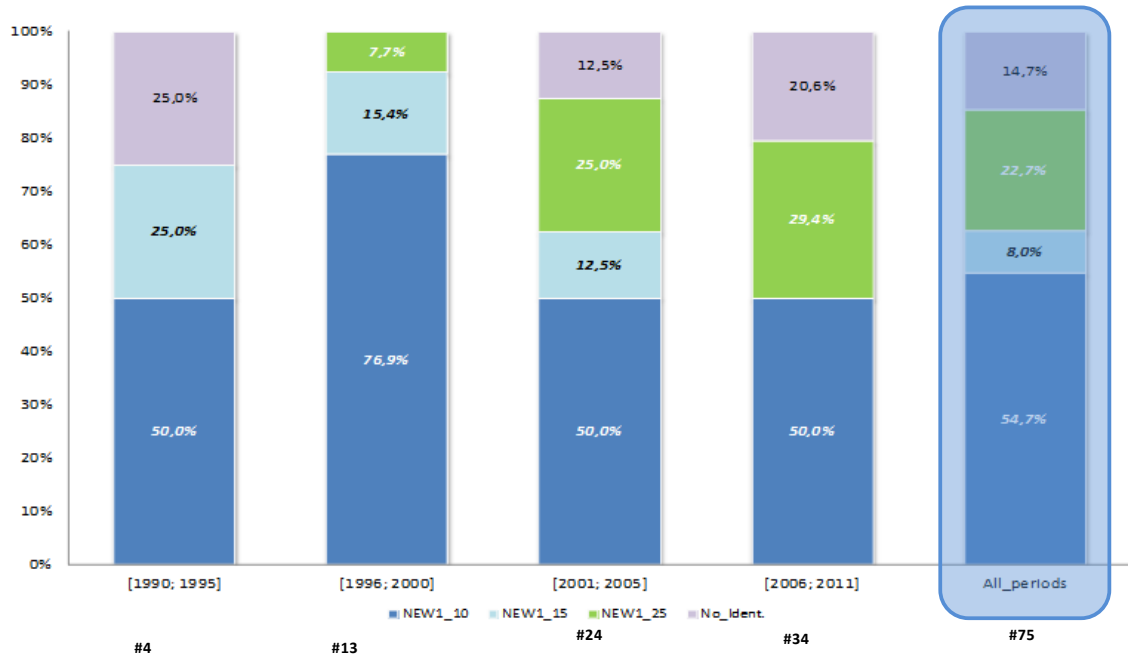

Figure 6: Distribution (%) of articles by 'firms' newness' criterion, 1990-2011

We identified three distinct options in terms of time intervals for NTBFs age: 'one to ten', 'one to fifteen' and 'one to twenty-five' years.

The analysis of the articles reveals that 41 papers define NTBFs based on a 'one to ten' period.[3] For the total period in study, 1990 up to 2011, 54,7% of total papers defined NTBFs resorting to this particular span of time (cf. Figure 6). Despite this general conclusion, the evolution is not smooth, registering a peak in the 1996-2000 period, when it accounted for 76,9% of the papers operationalizing this characteristic with reference to that period. The 'one to ten' time interval has lost some importance from the 1990s to 2000s.

The only argument sustaining the choice of the 'one to ten' period is explicitly referred by Yli-Renko et al. (2001: 539) who argue that "the ten year upper limit is consistent with previous research on entrepreneurial firms (e.g., Covin and Slevin, 1990; Ostgaard and Birley, 1994)".

Our bibliometric analysis also confirms that some authors associate the NTBFs concept with the definition of start-up (Lynskey, 2004; Colombo and Grilli, 2005a; Aspelung et al., 2005; Fukugawa, 2006; Colombo et al., 2010; West and Noel, 2009; Gao et al., 2010; Piva et al., 2011). But once more, the definition of start-up seems to differ across authors. Despite some vagueness that still remains, the term start-up is usually associated with a business at an initial stage of life. Almeida et al. (2003, in Teixeira and Tavares-Lehmann, 2007) and Oliveira and Teixeira (2011), associates this initial stage to a firm with 10 years or less.

Although the 'one to ten' obtains the authors' preferences at the global level, we reinforce the fact that the 'newness' criterion encompasses distinct time approaches.

It is possible to identify a second group of studies (e.g. Hogan and Hutson, 2005, 2006; Colombo et al., 2004, 2006, 2010; Colombo and Grilli, 2005a, 2005b, 2006, 2007, 2010; Bertoni et al., 2010a, 2010b, 2011; Ganotakis and Love, 2011) supporting their definition in Little's proposal (1977), which sustained a "NTBF as a business established for not more than 25 years" (Lindelöf and Löfsten, 2002: 145). This option seems to be increasingly chosen by researchers: the associated weight increased almost

[3] The database categorization was particularly difficult for this criterion. In the analyzed articles, NTBFs samples were obtained from specific databases or from particular case studies, covering distinct birth dates. We decided to systematize firm's age in 'one to ten', 'one to fifteen' and 'one to twenty-five' years (following Little's proposal), in terms of mean or absolute values.

four times from the period 1996-2000 to 2006-2011, from 7.7% to 29.4%. On the whole, this time interval was used by 22.7% of the total articles.

The studies based on RITA (Research on Entrepreneurship in Advanced Technologies) database, developed at the *Politecnico di Milano*, includes firms established in the 1980s and 1990s.

Finally, we identified a third category of papers which focus the NTBFs defined in the 'one to fifteen' period of birth (see Figure 6). Fontes and Coombs (1995, 2001) use this criterion. This option was also used by Pfirrmann (1999: 652) that referred that "the survey comprised firms which were no older than 15 years" and Aspelund et al. (2005). In the earlies 1990s, it seems to have been some interest in the 'one to fifteen' option, but it lost importance in the following two periods, in 1996-2000 and 2001-2005, decreasing to 15.4% and 12.5%, respectively. In the last period no reference to this 'New 1_15' was found. For the whole period, this time interval was used in 8% of the articles, representing 6 items.

Summing up, although Little's proposal has obtained increasing attention from authors, being the only definition that clearly defines the age criterion, the bibliometric analysis highlights that the 'one to ten' period in the most frequent operationalization of the firm age meaning that NTBFs are mostly considered 'start-ups'.

3) Size of the firms

NTBFs are often defined as small and medium firms (Butchart, 1987; Oakey et al., 1988) or initially small firms (Maine et al., 2010), linking two important issues - youth and smallness. Storey and Tether (1998b: 1057), clearly assume NTBFs as "new and small technology-based firms".

We consider the EC's (2003) categorization which encompasses micro, small and medium-sized enterprises, comprising firms that employ fewer than 250 workers. Within this SME category, a small firm employs fewer than 50 persons and a medium one employs (more than 50 but) fewer than 250 persons.

Around forty papers (54.7% of the total) refer to the size of the NTBFs, measured by the number of employees (cf. Figure 7).

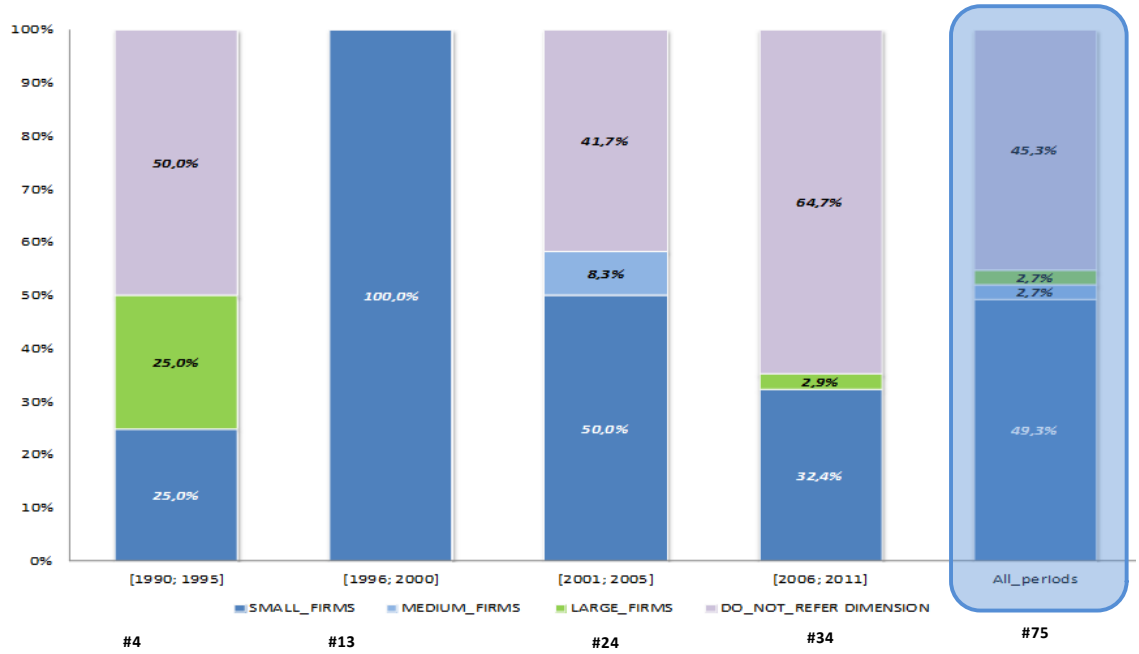

Figure 7: Distribution (%) of articles by size (number of employees), 1990-2011

The existing empirical studies comprise samples of firms that are mostly small (37), representing 49.3% of the total, and about 90% of those studies that refer firms' size - only two studies refer 'medium' firms and other two studies 'large' firms.

In dynamic terms, the tendency was to a relatively neglecting of the size dimension – the weight of the studies that do not operationalize this particular dimension drastically increased over time, from 0% in the 1996-2000 period, to 64.7% in the most recent period.

Size can also be operationalize by total annual turnover (EC, 2003). According to EC (2003), the category of micro, small and medium-sized firms (SMEs) is composed by firms which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.

Only a marginal fraction of the records on NTBFs considers size in terms of turnover - such dimension is present only in 7 studies (Autio, 1997b; Autio and Yli-Renko 1998a, 1998b; Autio and Lumme, 1998; Kollmer and Dowling, 2004; Hogan and Hutson, 2005 and Maine et al., 2010), representing 9.3% of the total (cf. Figure 8).

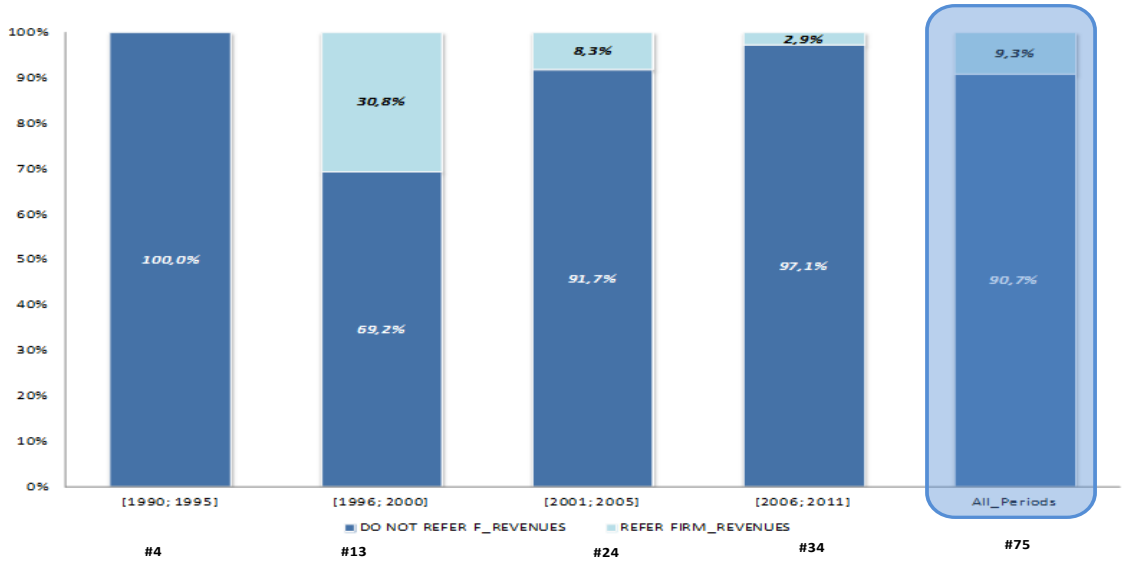

Figure 8: Distribution (%) by size (turnover), 1990-2011

4) Independence of the firm

Another issue the authors take particular attention in the sample identification concerning NBTFs, is the independence of the firm. Little (1977) explicitly identified this characteristic when he proposed the definition of NTBF.

The Bolton Committee (1971) defined a (small) firm as an independent socio-economic unit in the sense "that it does not form part of a larger enterprise and owner-managers are free from outside control in taking their principal decisions" (Stanworth and Curran, 1976: 96).

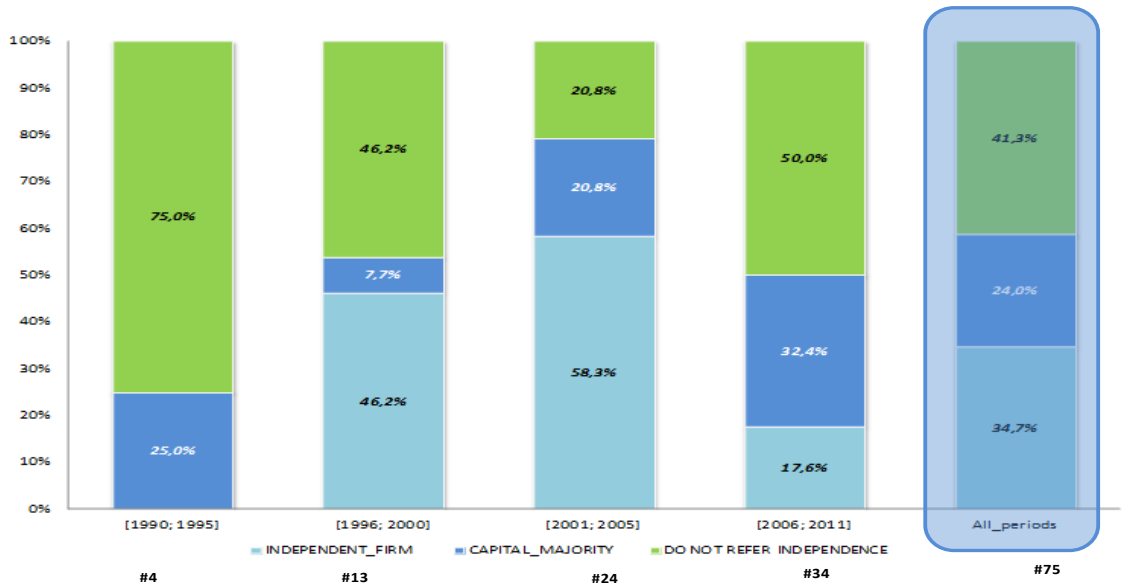

Figure 9: Distribution (%) by Independence criterion, 1990-2011

Following Little's definition (1977) of NTBF as an independently owned business, it is critical to guarantee that they do not belong to a larger enterprise.

The independence criterion emerges as a fundamental dimension in 44 out of 75 records of our database. Following the literature in the area, this dimension was measured in two ways:

1) independence as a single branch, which do not belong to a group or is a subsidiary of multinational or larger firms (e.g., Autio and Lumme, 1998; Almus and Nerlinger, 1999; Lindelöf and Löfsten, 2003; Dettwiler et al., 2006; Fukugawa, 2006; Coeurderoy and Murray, 2008), and

2) the majority of the capital structure belongs to the founding team (e.g., Fontes and Coombs, 1995, 2001; Igel and Islam, 2001; Colombo and Piva, 2008; Colombo et al., 2010; Brinckmann et al., 2011; Ganotakis and Love, 2011).

It is important to note that some operationalizing difficulties are observed when measuring this dimension as although independence might be guaranteed in the constitution date, it is difficult to ensure that the same remains by the end of the observation period (Fontes and Coombs, 1995, 2001; Laranja and Fontes, 1998).

Our bibliometric exercise confirms the association of the NTBFs independence criterion with distinct groups of firms. Studies which include samples from Finland, Sweden or Germany, choose the single branch dimension, whereas Italian or Portuguese samples are associated with Little's proposal.

Figure 9 shows that the independence criterion associated with the single branch condition gathers 34.7% of total articles, being that the relevance of this categorization changes over the period considered: 46.2 % in the initial period (1996-2000) down to 17.6% in the last period (2006-2011). In contrast, the criterion for independence, focused on capital majority, observes an increasing trend, with 7.7%% in the 1996-2000 period, and 32.4% in 2006-2011.

5) Founders characteristics

Many authors defend the fact that perhaps more important than technological knowledge for the success of NTBFs businesses, are their capabilities and human capital (Löfsten and Lindelöf, 2001; Colombo and Delmastro, 2002; Oakey, 2003;

Coster and Butler, 2005; Roskos and Klandt, 2007; Brinckmann et al. 2011), namely, knowledge and experience that enable firms to adapt successfully to changes in technology and markets (Colombo and Grilli, 2006, 2010; Ganotakis, 2010; Taheri and Geenhuizen, 2011).

The human perspective encompasses different dimensions and may include endowed abilities, experience, trained skills, attitudes and behaviors (Davenport, 1999), or highlight new features such as individual motivation, ambition and leadership (Mayo, 2001; O'Regan and Ghobadian, 2006).

Several studies (e.g., Colombo and Grilli, 2005b; Bianchi et al., 2011; Brinckmann et al., 2011) reinforce the characteristics related to the high level of education and know-how associated with NTBFs founders. In this perspective, firms are bundles of unique, difficult to imitate capabilities that are the main source of their sustainable competitive advantages (Grant, 1996). These distinctive capabilities of NTBFs are closely linked to the knowledge and skills of their founders, and thus to their human capital talents (e.g., Colombo and Grilli, 2010; Ganotakis, 2010; Taheri and Geenhuizen, 2011).

In terms of the operationalization of the NTBFs concept, we have confirmed that although many authors reinforce and study the linkage between the technological base of the firm and the scientific background of its founders (e.g. Donckels and Segers, 1990; Pfirmann, 1999 and Igel and Islam, 2001), human capital traits and capabilities of NTBFs founders are seldom incorporated in the proposed definitions (cf. Figure 10).

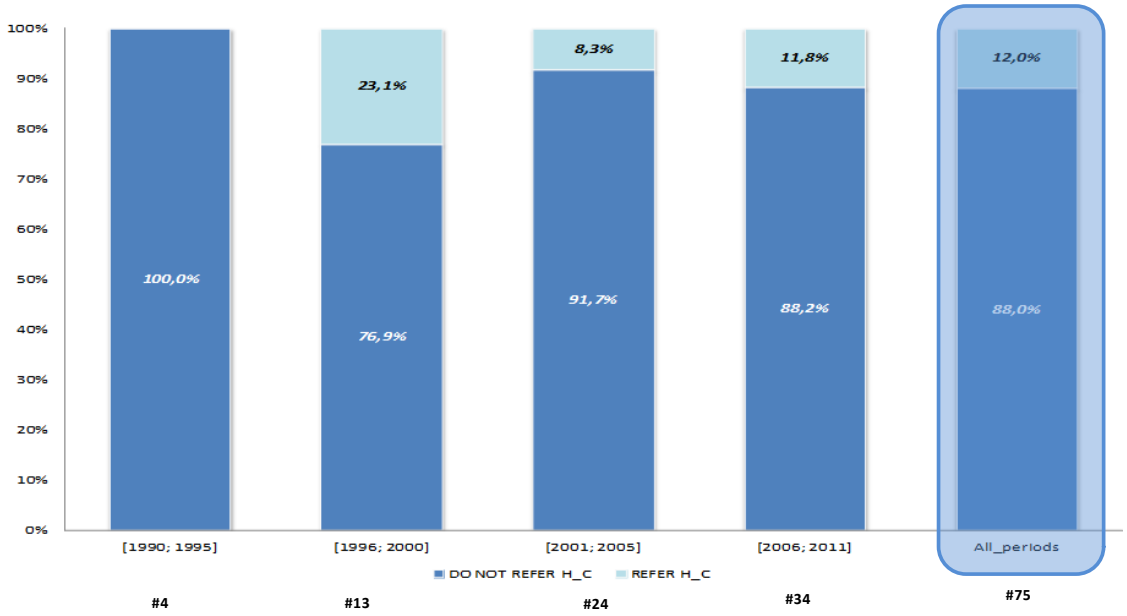

Figure 10: Distribution (%) of articles referring the human capital dimension, 1990-2011

Only 9 papers (12% of the total) in our database incorporate this specific dimension in the NTBFs definition.

Although a large number of studies have indeed documented that skilled human capital is a *sine qua non* condition for NTBFs creation (Baptista and Mendonça, 2010; Piva et al., 2011), the integration of the human dimension in the NTBFs definition is scarce.

∴

A large number of NTBFs definitions exist and are not consensual on which dimensions should be included. Based on the NTBFs literature revision and on the bibliometric analysis, we confirm the specificity of the concept of NTBF and the difficulty in its operationalization.

According to the bibliometric exercise undertook, the criteria that are associated with the concept of NTBF are the following:

1) Technology newness and industry emergence operationalized in terms of sector definition and high-tech measures;
2) Youth of the firm defined in terms of newness of NTBFs (mean age of the firms);
3) Size of the firm in terms of number of employees and sales;

4) Independence of the firm reflected by the fact that the majority of capital belongs to the NTBF teams;
5) Human capital of the founders team.

Within this list, as Table 5 shows, the most frequently used criteria by empirical studies in the area are 'newness', 'sector' definition and 'high-tech' association, each registering relative values above 70% in the 2000's.

Table 5: Different dimensions about NTBFs conceptualization – Systematization by number (and %) of articles

NTBFs Dimensions	[1996; 2000]	%	[2001; 2005]	%	[2006; 2011]	%	All Periods (number of articles)
Newness	13	***100%***	21	***87,5%***	27	***79,4%***	64
Sector	8	***61,5%***	21	***87,5%***	29	***85,3%***	62
High-Tech	6	***46,3%***	17	***70,8%***	25	***73,5%***	48
Independence	7	***53,9%***	19	***79,2%***	17	***50,0%***	44
Size Employees	13	***100%***	14	***58,3%***	12	***35,3%***	41
Human Capital	3	***23,1%***	2	***8,3%***	4	***11,8%***	9
Size Sales	4	***30,8%***	2	***8,3%***	1	***2,9%***	7

Note - % defined by weighting the value obtained in each criteria and the absolute n.º of publications.

In the bibliometric revision, we also identify a second group of NTBFs characteristics, 'independence' and 'size' (measured in terms of number of employees), that had lost relative relevance over the period in analysis.

A third group of characteristics, 'human capital' and 'size', measured in terms of NTBFs turnover/sales, presents low representativeness in the operationalization of the NTBF concept. Concerning this latter group, 'human capital' has been nevertheless gaining some relevance in defining NTBFs in practice, especially in the periods 2001-2005 to 2006-2011.

In Chapter 4, we assess whether a group of university spin offs can be considered NTBFs according to the criteria found above and establish the main differences between academic spin offs classified as NTBFs and those non NTBFs. Before that, in the next chapter (Chapter 3), we describe the methodology.

3. Methodological underpins

The expression ‘New technology-based firm’ (NTBFs) is commonly used in economics, but it is also supported by different conceptual understandings (Autio, 1997a; Storey and Tether, 1998a), as the analysis presented in Chapter 2 confirms. The bibliometric exercise undertook before, allowed us to arrive to a pragmatic concept of NTBFs based on a set of criteria put forward by the studies surveyed.

Resorting to the set of criteria that we found, we classify a group of firms which are likely to be considered as NTBFs: the firms ('academic spin-offs’) located in UPTEC, an incubator and science park of the Universidade do Porto (UP).

The UP manages four different incubation centers (U. Porto Science and Technology Park - UPTEC Incubation Centers), each of them operating in specific economic areas:

1) Sea Incubation Center - UPTEC MAR;
2) Creative Industries Incubation Center - UPTEC PINC;
3) Technological Incubation Center - UPTEC TECH;
4) Biotechnological Incubation Center - UPTEC BIO.

The universe of incubated firms, included by the end of 2010, 66 firms, encompassing a wide diversity of industries and technological fields. This is an adequate set for our exercise. As referred earlier, we aim at assessing the extent to which this group of firms might be or not categorized as NTBFs, according to the set of criteria that emerged from the literature on NTBFs.

For this purpose we construct a questionnaire, which was tested with one firm incubated in the UPTEC Centers. The purpose was to evaluate the clarity of questions and to introduce improvements on the initial proposal. An interview with the founders’ team permitted to confirm some problems related with specific questions and to introduce additional questions in order to gather information that would be interesting for our study.

The questionnaire was composed by 4 groups of questions, detailing the main proxies to operationalize the NTBFs characteristics.

The first group intends to identify the firm, containing questions regarding year of establishment, social capital structure, founding team and number of employees, activity

and financial data, covering turnover, R&D, exportations and patents. All these questions aimed to compare the firm evolution between the establishment date and the end of 2010, except the financial data which compared figures obtained in the first year of sales to the final year (2010).

In order to assess firm's technological skills, the second group of questions focused on the initial founding team in terms of qualifications and scientific knowledge and the third group proposed to evaluate the resources, brought to the business by each founder and to analyze the professional experience impact in the teams constitution. The fourth part of the questionnaire aimed at understanding the origin of technology and knowledge to the firm sustainability.

After the pilot phase, the final questionnaire[4] was sent to 58 firms by email between 15 and 30 of June 2011.

The firms were chosen after a previous selection, excluding projects in a pre-incubation situation (3 projects), associations (2 projects), specific projects to support R&D in partnership (2 projects) and a branch in Portugal from a multinational in the biopharmaceutical investigation field.

During July 2011, the data gathering process entered in a final phase and all the firms were re-contacted by email and then by phone.

At the end of the process, we obtained 30 responses, representing 51.7% of the selected population.

The responses were quantitatively analyzed and two groups were created: those categorized as NTBFs and those that were not considered NTBFs. Afterwards, we assess which were the key factors that distinguished these groups and proceeded to an in depth study of two groups of these firms.

[4] The questionnaire is presented in the Annex 2.

4. Empirical results

4.1. Finding out NTBFs in practice

The respondent sample is constituted by 30 firms, founded between 1994 and 2010, with 99 founders at the founding date. Analyzing the initial founding team, 92 of the founders were individuals and the other 7 were venture capital societies (3), an university, one I&D institution and firms (2).

By the end of 2010, these firms employed 152 workers, meaning that the firm's average size is around 5 employees. About 89% of total employees were university graduated.

The respondent sample comprises only small firms and, within this particular category, 29 of them are micro firms.[5] Although four firms employ more than 10 persons, only one of these obtained simultaneously an annual turnover above Euro 2 Million.

A significant proportion of the respondent firms belong to the 'Information and Software services' sector (33.3%), followed by 'Environmental technologies and energy' (20.0%), 'Internet based services' (13.3%) and 'Multimedia' (10.0%) sectors. The 'Biotechnology' and 'Telecommunications services' sectors represent 6.7% each. Finally, sectors such as 'New materials', 'Medical devices and instrumentation', 'R&D' and 'Edition' have residual positions, with 3.3% each. Hence, UPTEC sample is in line with the information gathered in the bibliometric exercise (Chapter 2), regarding the activity sector. Indeed, 'Information and Software services', 'Internet based services' and 'Multimedia' sectors emerge as prominent. Notwithstanding, the 'Environmental technologies and energy' sector holds a more important position in the UPTEC sample that it had on the bibliometric exercise and the 'Biotechnology' sector a less relevant position. Globally, the sample is composed by 10 different sectors.

As already mentioned, all the firms in our sample are small, with the majority being microenterprises, according with the double criteria proposed by EC (2003) – see Table 6.

[5] According to EC (2003), a microenterprise is defined as an enterprise which employs less than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million.

Table 6: Sample classification according with NTBFs characteristics

Sample Classification	*Newness [1_10]*	*High-Tech Sector*	*R&D Ratio*	*Independence*	*Size (n.º Employees)*	*Size (Sales)*	*Human Capital_ Dimension*
Criterion	29	29	17	28	30	30	29

Almost all the respondent firms are start-ups (less than 10 years in business) belonging to 'high-tech' sectors/industries.

The taking into account of the 'Independence' criterion excludes two firms from the category of NTBF, whereas the 'Human capital criterion' cuts off one firm from the NTBF classification.

Summing up, we observe that the criterion that impacts more on the NTBFs final classification is the 'High-Tech' definition, applying the OECD categories (cf. Table 2).

Taking all the criteria into account we conclude that only 14 out of the 30 firms of the sample might be classified as NTBFs.

In what follows, the categorization of firms as NTBF is explained and detailed for each criterion: Newness; High-Tech Sector and R&D ratio; Independence; Size (number of employees and sales); Human Capital.

1) Youth of the firm (Newness)

Using the same time reference as in the bibliometric exercise (Chapter 2), we distributed the UPTEC sample using five years period (cf. Figure 11).

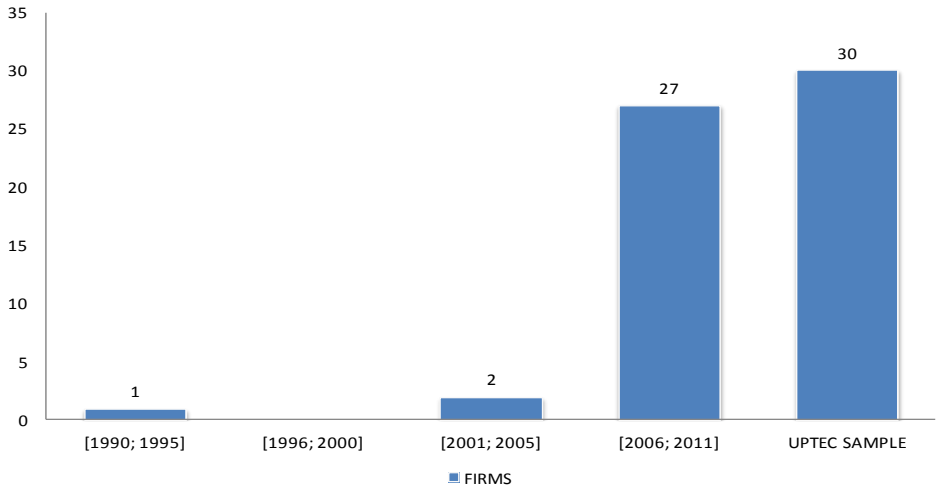

Figure 11: Number of firms by establishment date, 1990-2011

We observe that our sample is constituted by start-ups, the majority of them established in the last five years period. The firms in the sample are, on average, 3.7 years old.

Hence, the 'Newness' criterion is confirmed in this particular sample.

2) High-Tech Sector and R&D intensity

Our bibliometric revision confirmed the difficulty in operationalizing the criterion of technology intensity and also the fact that authors apply similar indicators that fall in two distinct groups. Monck et al. (1988, in Löfsten and Lindelöf, 2011: 312): "measures of resource inputs to high-technology activity, such as R&D effort, R&D expenditure and employment of qualified personnel and secondly measures of output or performance of high technology firms, such as growth rates, patent records and technological innovations".

Out of the 30 firms in the sample, 12 do not have investments in R&D and in one case R&D expenditures represent less than 5% of sales. Using the OECD taxonomy (cf. Table 2), NTBFs are those firms that present a R&D ratio above 5%, that is, are 'High-Tech' in OECD's nomenclature. Out of the 18 firms that perform R&D activities, 7 present an atypical R&D ratio (well above 100%), as they do not possess (yet) sales or register insignificant sales.

Analyzing the sample and their core-business activities, we classify 29 firms as NTBF looking at their sector characteristics. Many authors who studied the concept of NTBF (e.g., Laestadius, 1998; Dahlstrand and Jacobsson, 2003) find this particular classification too narrow.

3) Size of the firm

NTBFs are often defined as small (Storey and Tether, 1998b), medium firms (Butchart, 1987; Oakey et al., 1988), or initially small firms (Maine et al., 2010).

Although this characteristic has lost relevance over the five year periods in study, all the firms in UPTEC sample are small, in terms of both number of employees and sales, being most of them microenterprises.

4) Independence of the firm

Little's NTBFs definition was the most referred in our bibliometric exercise when we analysed the firms' independence issue since several authors refer to NTBFs as an independent owned business (Löfsten and Lindelöf, 2001, 2002; Lindelöf and Löfsten, 2002; Hogan and Hutson, 2005, 2006; Aaboen et al., 2006; Colombo et al., 2010 and Ganotakis and Love, 2011). This definition encompasses two dimensions: the group independence and the capital majority importance.

The Bolton Committee Report (1971) and Le Cornu et al. (1996) study, both cited in Hogan and Hutson (2005: 372), conclude that "the managerial independence is an important characteristic in small businesses". Under this perspective, "the independence was found to be the most important non-financial objective, (...), and critical to understanding the observed capital structure of SMEs".

Our sample was then analyzed under these two distinct perspectives and we concluded that no firm belongs to a large firm or multinational. The structures of social capital revealed that two companies had partners but with minority participation.

We identified in UPTEC sample participations in the capital structure of firms by venture capital societies. The participations guarantee that companies do not belong to a group or multinational, but do not guarantee the capital majority, because the venture capital investors do have representatives in the firms, confirming that the managerial independence concept is not fulfilled. In fact, when NTBFs obtain venture capital equity, the founding teams should accept losing some control of the business (Minola and Giorgino, 2008). However, since venture capital participations are understood to be temporary, we considered the two firms that were participated by venture capital societies as NTBFs.

5) Human capital

Founders' human capital is recognized as a primary asset for the competitive advantage of a NTBF (Cooper and Bruno, 1977; Colombo and Grilli, 2006, 2010), "as it is believed that only individuals who hold technical qualifications at the highest academic level will be able to form NTBFs, with the ability to exploit leading edge technologies and therefore introduce radically new and technologically complex, innovative products to a market" (Ganotakis, 2010: 4).

Nevertheless, several authors argue that the technological advantage may not be sufficient to successfully direct products or services to the market; in certain cases emerges the so-called 'technological myopia', progressively considered as a critical key to the success of firms (Miller, 2002; Antoniou and Ansoff, 2004). This occurs because the strategic direction from NTBFs must be determined by anticipating the future needs of the environment and markets, not only by knowing technological trends.

Hence, in order to have success in exploiting new business opportunities, complementary context-specific knowledge (e.g. marketing, management, strategy or property rights), that is generally dispersed among different individuals, needs to be combined and integrated (Colombo and Grilli, 2010; Bianchi et al., 2011).

In this line of reasoning, we analyzed the initial teams and identified the elements with strong connections with engineering and science. Although, as said, the technological dimension may not be sufficient, in general, authors agree that it is necessary to exploit leading edge technologies (Colombo and Delmastro, 2002; Ganotakis, 2010; Piva et al., 2011). Under this criterion definition, 29 firms are considered NTBFs.

4.2. Distinguishing NTBFs from non NTBFs in a sample of academic spin offs

In the previous section, resorting to the criteria gathered in the literature review and bibliometric exercise, we classified the academic spin off located in UPTEC in two main groups: NTBFs and non NTBFs. In the end of the process14 firms were classified as NTBFs and 16 not.

In the present section we analyze which are the main distinct characteristics between the two groups.

Given the small sample size, we used the Kruskal-Wallis nonparametric test for investigating the differences in mean of a set of relevant variables (e.g. Maroco, 2010).[6]

The incubation phenomenon is recent in the University of Porto and the UPTEC incubation centers exist since February 2007.

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6 Formally the hypotheses under study could be written as (considering the subgroups X1 = NTBFs and X2 = non NTBFs): ***H0***: F(X1) = F(X2) (The Kruskal-Wallis tests if the sample comes from population with the same distribution) vs. ***H1***: ∃ 1,2 F(X1) ≠ F(X2) (The Kruskal-Wallis tests if the sample comes from population with different distribution).

The incubated firms are, in general, as referred earlier, start-ups. No statistical difference emerged in this regards NTBFs (3.4 years in business) and non NTBFs (4.2 years in business) (cf. Table 7).

Regarding the general characteristics of the academic spin off located in UPTEC, the only two characteristics that emerged as (statistically, at 5% significance) distinctive is the amount of capital both at the beginning of the business and at the end of 2010. Indeed, the Kruskal Wallis test shows that NTBFs founders invested a substantial higher amount of money that their non NTBFs counterparts – about 4 times higher.

The size of the founding team (about 3 individuals in the beginning and in December 2010) and the size of the firms (almost no employees in the business starting phase and 5 by December 2010) are similar between the two groups. The same happens with the number of employees with tertiary (or higher) formal habilitations.

Table 7: General characteristics between the categories of firms

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Age	3,4	4,2	0,898
Capital _Constitution_Date	42.100 €	10.996 €	***0,038***
Capital_Dec_2010	96.824 €	26.179 €	***0,018***
Founding_Team_Constitution_Date	3,5	3,1	0,332
Founding_Team_Dec_2010	3,3	2,9	0,564
Employees_Constitution_Date	0,6	0,8	0,850
Employees_December_2010	4,5	5,7	0,600
Undergraduate_or_Higher_Constitution_Date	0,5	0,7	0,784
Undergraduate_or_Higher_December_2010	4,2	4,9	0,614

The background and complementarities of the top management team is usually understood as a competitive factor in NTBFs survival and development (Colombo and Grilli, 2005b, 2010; Bianchi et al. 2011; Brinckmann et al., 2011).

Regarding the founding team characteristics (Table 8), we gather a set of indicators - level and type of education in the initial founding teams, and number of years of experience in the specific business sector (Oliveira and Teixeira, 2011). Only in one indicator, Kruskal Wallis test evidence differences (at 10% significance) between

NTBFs and non NTBFs: weight of individuals in the founding team that possess managerial advanced knowledge (44% against 14% in NTBFs and non NTBFs respectively).

Table 8: Founding team's characteristics

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Majority Founding Team Undergraduate	0,44	0,29	0,397
Majority Founding Team Master Degree	0,19	0,21	0,857
At least One Phd	0,31	0,36	0,799
Majority Founding Team Technological K-How	0,87	0,71	0,280
Multidisciplinary Teams	0,56	0,36	0,269
Management Knowledge	***0,44***	***0,14***	***0,084***
Founding Team Experience	0,88	1,00	0,178
Founding Team Business Experience	0,50	0,71	0,240
Founding Team Experience More 10 Years	0,63	0,86	0,158
Founding Team Business Exp More 10 Years	0,25	0,29	0,828

This result seems to convey the idea that NTBFs in order to successfully exploit technology (Berry, 1996; Ganotakis, 2010; Becker (1993) in Taheri and Geenhuizen, 2011), also need market, long-term strategy and management knowledge (March-Chorda and Yagüe-Perales, 1999).

Educational level and the technological know-how did not emerged as statistically different between NTBFs and non NTBFs.

The literature sustains that NTBFs are entities with strong relations with the economic environment and innovation systems (Dahlstrand, 1997; Autio and Parkahangas, 1998; Druilhe and Garnsey, 2000). They are understood as an organic part of it (Autio, 1997a; Yli-Renko and Autio, 1998), through networking and linkages with universities and research institutions (Reitan, 1997; Malecki, 1981), incubators (Sternberg, 1990; Mian, 1996 Studdard, 2006; Yang et al., 2009; Scillitoe and Chakrabarti, 2010), business angels and venture capital societies (Madill et al., 2005) and large firms (Segers, 1993) in order to respond to the limitation in financial and organizational assets (Kelley and Nakoesteen, 2005) and to minimize their lack of resources. This perspective permits to assume that a NTBF can increase its effectiveness by accessing knowledge outside the organization (Kelley and Rice, 2002), brought by personal contacts and networking.

Our results seems to be at odds with the argumentation above as contacts (and capital & contacts) emerge as significantly more important for the non NTBF group (with more than half of the founders indicating this reasons) than for the NTBFs (only 13% indicated such reasons for starting or joining the business in its early phase).

Table 9: Reasons to start a business

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Majority Fteam Entering Reasons_Capital	0,81	0,71	0,533
Majority Fteam Entering Reasons_Contacts	***0,13***	***0,57***	***0,011***
Majority Fteam Entering Reasons_Knowledge	0,56	0,64	0,659
Majority Fteam Entering Reasons_Patents	0,00	0,00	1,000
Majority Fteam Entering Reasons_Capital & Contacts	***0,13***	***0,50***	***0,028***
Majority Fteam Entering Reasons Cap.&Contacts&Know	0,13	0,29	0,280

Regarding innovation and technology acquisition traits (cf. Table 10), statistical results revealed an homogeneity in technological processes of transference, development and acquisition among NTBFs and non NTBFs.

Table 10: Businesses innovation and technology acquisition traits

Variables	*NTBFs Means*	*Non NTBFs Means*	*p-value*
Product	***0,25***	***0,00***	***0,048***
Service	***0,19***	***0,50***	***0,075***
Product_Service	0,56	0,50	0,736
R&D Ratio_1.st Year_Sales	***0,07***	***0,00***	***0,010***
R&D Ratio_2010	***8,17***	***0,04***	***0,000***
Export/Sales Ratio_1.st_Year_Sales	***0,07***	***0,00***	***0,094***
Export/Sales Ratio_2010	***0,18***	***0,02***	***0,012***
Registered_Patents_Constitution_Date	0,00	0,07	0,285
Registered_Patents_2010	0,31	0,21	0,972
Technology Transference_UP_Department	0,38	0,43	0,769
Technology Transference Investigation_Center	0,19	0,14	0,748
Technology Development_Consortium	0,13	0,07	0,631
Technology In-House_Development	0,81	0,71	0,533
Technology Acquisition_Portugal	0,19	0,36	0,303
Technology Acquisition_Importation	0,06	0,29	0,108

In contrast, significant differences emerged in firms' business type with NTBFs being much more exclusively product based firms (25% vs 0% in the case of non NTBFs) and non NTBFs relatively more service based (50% vs 19% in the case of NTBFs).

NTBFs emerged as much more R&D and export intensive both at the beginning and in December 2010 than non NTBFs.

Interestingly, some studies argue (e.g., Coeurderoy and Murray, 2008; Ganotakis and Love, 2011; Taheri and Geenhuizen, 2011) that international activities of NTBFs have become an additional opportunity to explore a competitive advantage in foreign markets (Sapienza et al., 2006), specially to open economies such as Portugal (Silva et al., 2010; Oliveira and Teixeira, 2011).

5. Conclusions

> "There is no doubt that new, technology-based firms are a phenomenon of major economic importance" (Autio, 1997a: 195).

NTBFs explain deep technological changes, economic growth and competitiveness, and depend "not only on the work of scientists and engineers, but also on a wider range of economic and societal factors" (Teixeira and Lopes, 2012 in Teixeira, 2012: 8).

Since the related literature revealed awareness of the relevance of NTBFs, but was spread and somewhat vague in the sense that it proposes several, alternative definitions of NTBFs, the main purpose with this dissertation was to clarify and operationalize the concept, preventing "the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based", Coase (1937: 386).

The bibliometric exercise developed in Chapter 2 permitted to study the characteristics of NTBFs in an integrated and systematic way, since we collected information on a vast set of definitions of NTBFs. Based on 75 articles which put forward distinct definition for NTBFs, we construct a database through which it was possible to define a set of criteria to clarify the concept of NTBF. Based on a quantitative analysis of the several definitions, we identified the relevant characteristics and proposed criteria to identify NTBFs.

To the best of our knowledge, no similar methodological exercise was done before, so we consider this effort as giving a new perspective about the conceptualization of NTBFs. The second phase of this dissertation consisted in applying the above set of criteria to a specific sample of firms – the academic spin offs (ASOs). Since ASOs are usually interchangeably identified as NTBFs, considered to be important drivers of economic change and growth, that contribute to the transformation of university knowledge into successful businesses (e.g., Taheri and Geenhuizen, 2011), we decided to use these firms as unit of analysis.

The empirical data was gathered through a direct questionnaire targeting 58 new firms incubated in the UPTEC (Universidade do Porto Science Park). We managed to get 30 valid responses, which corresponded to an effective response rate of 51.7%.

By using the NTBFs criteria obtained through the bibliometric exercise, it was possible to conclude that, contrary to common wisdom, not all ASOs are NTBFs. Indeed, only 46.7% of the ASOs were classified as NTBFs.

Additionally, the academic spin offs classified as NTBFs according to our criteria distinguish significantly from the other ASOs, in terms of higher level of capital invested, higher R&D and internationalization intensity and founding teams with higher presence of individuals with management capabilities.

The present work open some challenging questions namely to what extent academic spin offs that are NTBFs perform better than the non NTBFs and whether NTBFs located in other science parks would behave or possess distinct characteristics than those found in our limited sample. This would require the enlargement of the target population to more universities and their science parks and incubators and the resort to more sophisticated statistical and econometric tools.

References

Aaboen L., Lindelöf P., Koch C.V. and Löfsten H. (2006), "Corporate governance and performance of small high-tech firms in Sweden", *Technovation,* Vol. 26, pp. 955-968.

Almus M. and Nerlinger E.A. (1999), "Growth of new technology-based firms: Which factors matter?", *Small Business Economics,* Vol. 13, pp. 141-154.

Antoniou P.H and Ansoff H.I. (2004), "Strategic management of technology", *Technology Analysis & Strategic Management,* Vol. 16, pp. 275-291.

Aspelung A., Berg-Utby T. and Skjevdal R. (2005), "Initial resources' influence on new venture survival: A longitudinal study of new technology-based firms", *Technovation,* Vol. 25, pp. 1337-1347.

Autio E. (1994), "Four types of innovators. A conceptual and empirical study of new technology-based companies as innovators", Helsinki University of Technology.

Autio E. (1997a), "Atomistic and systemic approaches to research on new, technology-based firms: A literature study", *Small Business Economics,* Vol. 9, pp. 195-209.

Autio E. (1997b), "New, technology-based firms in innovation networks symplectic and generative impacts", *Research Policy,* Vol. 26, pp. 263-281.

Autio E. (2000), "*Growth of technology-based new firms*", D. L. Sexton and H. Landstrom (Eds.), Handbook of entrepreneurship, Oxford: Blackwell Publishers.

Autio E. and Lumme A. (1998), "Does the innovator role affect the perceived potential for growth? Analysis of four types of new technology-based firms", *Technology Analysis & Strategic Management*, Vol. 10, Nº 1, pp. 41-54.

Autio E. and Parhankangas A. (1998), "Employment generation potential of new, technology-based firms during a recessionary period: The case of Finland", *Small Business Economics,* Vol. 11, pp. 113-123.

Autio E. and Yli-Renko H. (1998a), "New, technology-based firms in small open economies - An analysis based on the Finnish experience", *Research Policy* 26, 973–987.

Autio E. and Yli-Renko H. (1998b), "New, technology-based firms as agents of technological rejuvenation", *Entrepreneurship & Regional Development*, Vol. 10, pp. 71-92.

Baptista R. and Mendonça J. (2010), "Proximity to knowledge sources and the location of knowledge-based start-ups", *Annals of Regional Studies*, Vol. 45, Nº 1, 5-29.

Berry M. (1996), "Technical entrepreneurship, strategic awareness and corporate transformation in small high-tech firms", *Technovation*, Vol. 16, pp. 487-522.

Bertoni F., Colombo M.G. and Croce, A. (2010a), "The effect of venture capital financing on the sensitivity to cash flow of firm's investments", *European Financial Management*, Vol. 16, Nº 4, pp. 528–551.

Bertoni F., Croce A. and D'Adda D. (2010b), "Venture capital investments and patenting activity of high-tech start-ups: A micro-econometric firm-level analysis", *Venture Capital*, Vol. 12, Nº 4, pp. 307-326.

Bertoni F., Colombo M.G. and Grilli L. (2011), "Venture capital financing and the growth of high-tech start-ups: Disentangling treatment from selection effects", *Research Policy*, Vol. 40, pp. 1028-1043.

Bianchi M., Chiaroni D., Chiesa V. and Frattini F. (2011), "Exploring the role of human resources in technology out-licensing: an empirical analysis of biotech new technology-based firms", *Technology Analysis & Strategic Management*, Vol. 23, Nº 8, pp. 825-849.

Bollinger L., Hope K. and Utterback J.M. (1983), "A review of literature and hypotheses on new technology-based firms", *Research Policy*, Vol. 12, pp. 1-14.

Brinckmann J., Salomo S. and Gemuenden H.G. (2011), "Financial management competence of founding teams and growth of new technology-based firms", *Entrepreneurship: Theory and Practice*, Vol. 35, Nº 2, pp. 217-243.

Buganza T., Gerst M. and Verganti R. (2010), "Adoption of NPD flexibility practices in new technology-based firms", *European Journal of Innovation Management*, Vol. 13, Nº 1, pp. 62-80.

Butchart, R.I. (1987). "A new UK definition of the high technology industries", *Economic Trends*, Vol. 40, pp. 82-88.

Candi M. and Saemundsson R. (2008), "Oil in water? Explaining differences in aesthetic design emphasis in new technology-based firms", *Technovation*, Vol. 28, pp. 464-471.

Candi M. and Saemundsson R. (2011), "Exploring the relationship between aesthetic design as an element of new service development and performance", *Journal of Product Innovation Management*, Vol. 28, pp. 536-557.

Chamanski A. and Waag S. (2001), "The organizational success of new, technology-based firms", *working paper*, Norwegian university of Science and Technology, Trondheim.

Coase R.H. (1937), "The nature of the firm", *Economica New Series*, Vol. 4, Nº 16, 386-405.

Coeurderoy R. and Murray G. (2008), "Regulatory environments and the location decision: evidence from the early foreign market entries of new technology-based firms", *Journal of International Business Studies*, Vol. 39, pp. 670-687.

Colombo M.G. and Delmastro M. (2002), "How effective are technology incubators? Evidence from Italy", *Research Policy*, Vol. 31, pp. 1103-1122.

Colombo M.G. and Grilli, L. (2005a), "Start-up size: The role of external financing", *Economics Letters*, Vol. 88, pp. 243-250.

Colombo M.G. and Grilli, L. (2005b), "Founders' human capital and the growth of new technology-based firms: A competence-based view", *Research Policy*, Vol. 34, pp. 795-816.

Colombo M.G. and Grilli L. (2006), "Supporting high-tech start-ups: Lessons from Italian technology policy", *International Entrepreneurship Management Journal*, Vol. 2, pp. 189-209.

Colombo M.G. and Grilli L. (2007), "Funding gaps? Access to bank loans by high-tech start-ups", *Small Business Economics*, Vol. 29, pp. 25-46.

Colombo M.G. and Grilli L. (2010), "On growth drivers of high-tech start-ups: Exploring the role of founders' human capital and venture capital", *Journal of Business Venturing*, Vol. 25, Nº 6, pp. 610-626.

Colombo M.G. and Piva E. (2008), "Strengths and Weaknesses of Academic Startups: A Conceptual Model", *IEEE Transactions on Engineering Management*, Vol. 55, Nº 1, pp. 37-49.

Colombo M.G., Delmastro M. and Grilli L. (2004), "Entrepreneurs' human capital and the start-up size of new technology-based firm", *International Journal of Industrial Organization*, Vol. 22, pp. 1183-1211.

Colombo M.G., Grilli, L. and Piva E. (2006), "In search of complementary assets: The determinants of alliance formation of high-tech start-ups", *Research Policy*, Vol. 35, pp. 1166-1199.

Colombo M.G., D'Adda D. and Piva E. (2010), "The contribution of university research to the growth of academic start-ups: an empirical analysis", *Journal of Technology Transfer*, Vol. 35, pp. 113–140.

Cooper A.C. (1971), "*The founding of technologically-Based Firms*", Milwaukee: The Center for Venture Management.

Cooper A.C. and Bruno A.V. (1977), "Success among high-technology firms", *Business Horizons*, Vol. 20, pp. 16-22.

Coster R. De and Butler C. (2005), "Assessment of proposals for new technology ventures in the UK: characteristics of university spin-off companies", *Technovation*, Vol. 25, pp. 535-543.

Davenport T.O. (1999) "Human capital", *Management Review*, Vol. 88, Nº 11, pp. 37-42.

Dahlstrand A.L. (1997), " Entrepreneurial Spin-off Enterprises in Göteborg, Sweden", *European Planning Studies*, Vol. 5 Nº 5, pp. 659-673.

Dahlstrand A.L. (1999), "Technology-based SMEs in Goteborg Region: Their origin and interaction with Universities and large firms", *Regional Studies*, Vol. 33, pp. 379-389.

Dahlstrand A.L. (2007), "Technology-based entrepreneurship and regional development: The case of Sweden", *European Business Review*, Vol. 19, Nº 5, pp. 373-386.

Dahlstrand A.L. and Jacobsson S. (2003), "Universities and technology-based entrepreneurship in the Gothenburg Region", *Local Economy*, Vol. 18, Nº 1, pp. 80-90.

Delapierre M., Madeuf B. and Savoy A. (1998), "NTBFs - The French case", *Research Policy*, Vol. 26, pp. 989-1003.

Delaney E.J. (1993), "Technology search and firm bounds in Biotechnology: New firms as agents of change", *Growth and Change*, Vol. 14, pp. 206-228.

Dettwiler P., Lindelöf P. and Löfsten H. (2006), "Utility of location: A comparative survey between small new technology-based firms located on and off Science Parks - Implications for facilities management", *Technovation,* Vol. 26, pp. 506-517.

Donckels R. and Segers J.P. (1990), "New technology based firms and the creation of regional growth potential - Theoretical considerations and empirical evidence for Belgium", *Small Business Economics,* Vol. 2, pp. 33-44.

Dosi G. (1984), "*Technical Change and Industrial Transformation",* Macmillan, London.

Druilhe C. and Garnsey E. (2000), "Emergence and growth of high-tech activity in Cambridge and Grenoble", *Entrepreneurship & Regional Development*, Vol. 12, pp. 163-177.

European Union (2003), "*Commission Recommendation concerning the definition of micro, small and medium-sized enterprises, 6 May 2003*", Official Journal of the European Union".

Elorz K.S. (2003), "*La creación de empresas de base tecnológica. Una experiencia práctica*", Proyecto para la promoción de empresas innovadoras de base tecnológica, ANCES 2003.

Fontes M. and Coombs R. (1995), "New technology-based firms and technology acquisition in Portugal: Firms' adaptive responses to a less favourable environment", *Technovation,* Vol. 15, Nº 8, pp. 497-510.

Fontes M. and Coombs R. (1996), "New technology-based firm formation in a less advanced country: a learning process", *International Journal of Entrepreneurial Behavior and Research,* Vol. 2, pp. 82-101.

Fontes M. and Coombs R. (2001), "Contribution of new technology-based firms to the strengthening of technological capabilities in intermediate economies", *Research Policy,* Vol. 30, pp. 79-97.

Freeman C. (1993), "Technical change and unemployment: the links between macro-economic policy and innovation policy", paper presented to the Conference on Technology, Innovation Policy and Employment, organized by the OECD and the Finnish Government, 7-9 October Helsinki.

Forrest J.E. (1990), "Strategic alliances and the small technology-based firm", *Small Business Management,* Vol. 28, Nº 3, pp. 37-45.

Fukugawa N. (2006), "Science parks in Japan and their value-added contributions to new technology-based firms", *International Journal of Industrial Organization,* Vol. 24, pp. 381-400.

*G*ao J., Li J., Chey Y. and Shi S. (2010), " Impact of initial conditions on new venture success: A longitudinal study of new technology-based firms", *International Journal of Innovation Management,* Vol. 14, pp. 41-56.

Ganotakis P. (2010), "Founders' human capital and the performance of UK new technology based firms", *Small Business Economics,* Published online: 24 December 2010.

Ganotakis P. and Love J.H. (2011), "R&D, product innovation and exporting: evidence from UK NTBFs", *Oxford Economic Papers,* Vol. 63, pp. 279-306.

Godin B. (2004), "The obsession for competitiveness and its impact on statistics: the construction of high-technology indicators", *Research Policy,* Vol. 33, pp. 1217-1229.

Grant R.M. (1996), "Prospering in Dynamically-Competitive Environments: Organizational Capability as Knowledge Integration", *Organization Science*, Vol. 7, pp. 375-387.

Grinstein A. and Goldman A. (2006), "Characterizing the technology firm: An exploratory study", *Research Policy*, Vol. 35, pp. 121-143.

Hogan T. and Hutson E. (2005), "Capital structure in new technology-based firms: Evidence from the Irish software sector", *Global Finance Journal*, Vol. 15, pp. 369- 387.

Hogan T. and Hutson E. (2006), "The relation between key events in the development phase and the financial structure of NTBFs in the software sector", *International Entrepreneurship Management Journal*, Vol. 2, pp. 227-243.

Igel B. and Islam N. (2001), "Strategies for service and market development of entrepreneurial software designing firms", *Technovation*, Vol. 21, pp. 157-166.

Kaplinsky R. (1981), "*Firm Size and Technical Change in a Dynamic Context*", (mimeo), Institute of Development Studies, University of Sussex, UK, August.

Keeble D., Lawson C, Smith H.L., Moore B. and Wilkinson F. (1998), "Internationalization processes, networking and local embeddedness in technology-intensive small firms", *Small Business Economics*, Vol. 11, pp.327-342.

Kelley D. and Nakosteen R. (2005), "Technology resources, alliances, and sustained growth in new, technology-based firms", *IEEE Transactions on Engineering Management*, Vol. 52, Nº 3, pp. 292-300.

Kelley D. and Rice M.P. (2002), "Leveraging the value of proprritary technologies", *Journal of Small Business Management*, Vol. 40, Nº 1, pp. 1-16.

Klofsten M. (1994), "Technology-based firms: Critical aspects of their early development", *Journal of Enterprising Culture*, Vol. 2, pp. 535-557.

Klofsten M. and Jones-Evans D. (1996), "Stimulation of technology-based small firms - A case of university-industry cooperation", *Technovation*, Vol. 16, pp. 187-193.

Kollmer H. and Dowling M. (2004) "Licensing as a commercialization strategy for new technology-based firms", *Research Policy*, Vol. 33, pp. 1141–1151.

Laestadius S. (1998), "The relevance of science and technology indicators: The case of pulp and paper", *Research Policy*, Vol. 27, pp. 385–95.

Laranja M. and Fontes M. (1998), "Creative adaptation: The role of new technology based firms in Portugal", *Research Policy*, Vol. 26, pp. 1023-1036.

Lindelöf P. and Löfsten H. (2002), "Growth, management and financing of new technology-based firms - Assessing value-added contributions of firms located on and off Science Parks", *Omega*, Vol. 30, pp. 143-154.

Lindelöf P. and Löfsten H. (2003), "Science park location and new technology-based firms in Sweden - Implications for strategy and performance", *Small Business Economics*, Vol. 20, pp. 245-258.

Lindelöf P. and Löfsten H. (2004), " Proximity as a resource base for competitive advantage: University–industry links for technology transfer", *Journal of Technology Transfer*, Vol. 29, pp. 311-326.

Lindelöf P. and Löfsten H. (2006), "Environmental hostility and firm behavior - An empirical examination of new technology-based firms on Science Parks", *Journal of Small Business Management*, Vol. 44, Nº 3, pp. 386-406.

Little A.D. (1977), "*New Technology Based Firms in the UK and the FRG*", Wilton House Publications, London.

Löfsten H. and Lindelöf P. (2001), "Science parks in Sweden: Industrial renewal and development?", *R&D Management*, Vol. 31, Nº 3, pp. 309-322.

Löfsten H. and Lindelöf P. (2002), "Science Parks and the growth of new technology-based firms - Academic-industry links, innovation and markets", *Research Policy*, Vol. 31, pp. 859-876.

Löfsten H. and Lindelöf P. (2003), "Determinants for an entrepreneurial milieu: Science Parks and business policy in growing firms", *Technovation*, Vol. 23, pp. 51-64.

Löfsten H. and Lindelöf P. (2005a), "Environmental hostility, strategic orientation and the importance of management accounting - An empirical analysis of new technology-based firms", *Technovation*, Vol. 25, pp. 725-738.

Löfsten H. and Lindelöf P. (2005b), "R&D networks and product innovation patterns - Academic and non-academic new technology-based firms on Science Parks", *Technovation*, Vol. 25, pp. 1025-1037.

Lynskey M.J. (2004), "Knowledge, finance and human capital: The role of social institutional variables on entrepreneurship in Japan", *Industry and Innovation*, Vol. 11, Nº 4, pp. 373-405.

Madill J., Haines Jr. G.H. and Riding A.L. (2005), "The role of angels in technology SMEs: A link to venture capital", *Venture Capital*, Vol. 7, Nº 2, pp. 107-129.

Malecki E. (1981), "Science, technology, and regional economic development: Review and prospects", *Research Policy*, Vol. 10, pp. 312-334.

March-Chorda I. and Yagüe-Perales R. (1999), "A new tool to classifying new technology-based firm prospects and expectations", *Journal of High Technology Management Research*, Vol. 10, Nº 2, pp. 347-376.

Maroco J. (2010), "*Análise Estatística com utilização do SPSS*", Edições Sílabo, Lisboa.

Mason C. and Harrison R. (1994), "The role of informal and formal sources of venture capital in the financing of technology-based SMEs in the United Kingdom", in Oakey, R. (ed.) "*New Technology-based Firms in the 1990s"*, Paul Chapman Publishing Ltd., London.

Mayo A. (2001), "*The Human Value of the Enterprise: Valuing People as Assets - Monitoring, Measuring, Managin*g", Nicholas Brealey Publishing, London.

Meyer M. H. and Roberts E.B. (1986), "New Product strategy in small technology-based firms", *Management Science*, Vol. 32, pp. 806-821.

Maine E.M., Shapiro D.M. and Vining A.R. (2010), "The role of clustering in the growth of new technology-based firms", *Small Business Economics*, Vol. 34, pp. 127-146.

Mian S.A. (1996), "Assessing value-added contributions of university technology business incubators to tenant firms", *Research Policy*, Vol. 25, pp. 325-335.

Miller K.D. (2002), "Knowledge inventories and managerial myopia", *Strategic Management Journal*, Vol. 23, pp. 689-706.

Minola T. and Giorgino M. (2008), "Who's going to provide the funding for high tech start-ups? A model for the analysis of determinants with a fuzzy approach", *R&D Management*, Vol. 38, Nº 3, pp. 335-351.

Oakey R., Rothwell R. and Cooper S. (1988), "*The Management of Innovation in High Technology Small Firms"*, Pinter, London.

Oakey R. (1991), "High technology small firms: their potential for rapid industrial growth", *International Small Business Journal*, Vol. 9, pp. 30-42.

Oakey R. (1994), "*New Technology-based Firms in the 1990s"*, Paul Chapman, London.

Oakey R. (2003), "Funding innovation and growth in UK new technology-based firms: some observations on contributions from the public and private sectors", *Venture Capital*, Vol. ,5 Nº 2, 161-179.

Oliveira P. and Teixeira A. (2011), "The internationalization profiles of Portuguese SMEs", FEP Working Papers n.º 439, Faculdade de Economia, Universidade do Porto.

O'Regan N. and Ghobadian A. (2006), "Innovation in NTBFs: Does leadership really matter?", *International Entrepreneurship Management Journal* Vol. 2, pp. 299-314.

Piva E., Grilli L. and Rossi-Lamastra C. (2011), "The creation of high-tech entrepreneurial ventures at the local level: The role of local competences and communication infrastructures", *Industry and Innovation*, Vol. 18, Nº 6, pp. 563-580.

Pfirrmann O. (1999), "Neither soft nor hard — Pattern of development of new technology based firms in biotechnology", *Technovation*, Vol. 19, pp. 651-659.

Reitan B. (1997), "Fostering technical entrepreneurship in research communities: Granting scholarships to would-be entrepreneurs", *Technovation,* 17, Nº 6, pp. 287-296.

Rickne A. and Jacobsson S. (1996), "New technology-based firms - An exploratory study of technology exploitation and industrial renewal", *International Journal of Technology Management,* Vol. 11, Nº 3/4, pp. 238-257.

Rickne A. and Jacobsson S. (1999), "New technology-based firms in Sweden - A study of their impact on industrial renewal", *Economic Innovation New Technology,* Vol. 8, pp. 197-223.

Robb A.M. and Coleman S. (2010), "Financing strategies of new technology-based Firms: A comparison of women and men owned firms", *Journal Technology Management & Innovation*, Vol. 5, Nº 1, pp. 30-50

Roberts E.B. and Weiner H.A. (1966), "Some characteristics of technical entrepreneurs", *Research Program on the Management of Science and Technology*, #195-66.

Roskos S. and Klandt H. (2007), "Young technology ventures in Europe: Aspects of market orientation and entrepreneurial orientation", *Regional Frontiers of Entrepreneurship Research 2006 - Best paper awards*, pp. 21-41.

Rothwell R. (1989), "Small Firms, Innovation and Industrial Change", *Small Business Economics,* Vol. 1, pp. 51-64.

Rothwell R. and Zegveld W. (1985), "*Reindustrialization and Technology"*, Longman, London.

Sapienza H., Autio E., George G. and Zahra S.A. (2006), "A capabilities perspective on the effects of early internationalization on firm survival and growth", *Academy of Management Review*, Vol. 31, Nº 4, pp. 914-933.

Scillitoe J.L. and Chakrabarti A.K. (2010), "The role of incubator interactions in assisting new ventures", *Technovation,* Vol. 30, Nº 3, pp. 155-167.

Segers J.P. (1993), "Strategic partnering between new technology based firms and large established firms in the biotechnology and micro-electronics industries in Belgium", *Small Business Economics,* Vol. 5, pp. 271-281.

Shearman C. and Burrell G. (1988), "New technology-based firms and the emergence of new industries: Some employment implications", *New Technology Work Employment*, Vol. 3, Nº 2, pp. 87–99.

Silva A, Africano A.P. and Afonso O. (2010), "Do Portuguese manufacturing firms self select to exports?", FEP Working Papers n.º 371, Faculdade de Economia, Universidade do Porto.

Smith K. (2005), 'Measuring innovation', in J. Fagerberg, D. Mowery and R. Nelson (Eds.), *The Oxford Handbook of Innovation*, Chapter 6, Oxford, Oxford University Press.

Stanworth M.J.K. and Curran J. (1976), "Growth and the small firm: An alternative view", *The Journal of Management Studies*, Vol. 1, pp. 95-110.

Sternberg R. (1990), "The impact of innovation centres on small technology-based firms: The example of the Federal Republic of Germany", *Small Business Economics*, Vol. 2, pp. 105-118.

Storey D.J. and Tether B.S. (1998a), "New technology-based firms in the European Union: An introduction", *Research Policy*, Vol. 26, pp. 933-946.

Storey D.J. and Tether B.S. (1998b), "Public policy measures to support new technology-based firms in the European Union", *Research Policy*, Vol. 26, pp. 1037-1057.

Studdard N. (2006), "The effectiveness of entrepreneurial firm's knowledge acquisition from a business incubator", *International Entrepreneurship Management Journal*, Vol. 2, pp. 211-225.

Taheri M. and Geenhuizen M.v. (2011), "How human capital and social networks may influence the patterns of international learning among academic spin-off firms", *Regional Science*, Vol. 90, Nº 2, pp. 287-312.

Teixeira A.C. (2012), "*Technological Change*", Aurora Teixeira, InTech. Croacia.

West III P. and Noel T.W. (2009), "The Impact of Knowledge Resources on New Venture Performance", *Journal of Small Business Management*, Vol. 47 Nº 1, pp. 1-22.

Yang C.H., Kazuyuki Motohashi K. and Chen J.R. (2009), "Are new technology-based firms located on science parks really more innovative? Evidence from Taiwan", *Research Policy*, Vol. 38, pp. 77-85.

Yli-Renko H. and Autio E. (1998), "The network embeddedness of new, technology-based firms: Developing a systemic evolution model", *Small Business Economics*, Vol. 11, pp. 253-267

Yli-Renko H., Sapienza H.J. and Hay M. (2001), "The role of contractual governance flexibility in realizing the outcomes of key customer relationships", *Journal of Business Venturing*, Vol. 16, pp. 529-555.

Annex 1: Database Bibliometric Revision - NTBFs Criterion

N.º	INITIAL LIST	AUTHORS	TITLE	DATE	NEW 1_10'	NEW_1_15'	NEW 1_25'	AVERAGE REVENUES	GROWTH RATE	SIZE SMALL	SIZE MEDIUM	SIZE LARGE	HUMAN CAPITAL DIMENSION	INDEPENDENT FIRMS	CAPITAL MAJORITY FTEAM	HIGH-TECH
1	2	Bianchi et al.	Exploring the role of human resources in technology out-licensing: an empirical analysis of biotech new technology-based firms.	2011	1	0	0	0	0	0	0	1	1	0	0	0
2	3	Bertoni et al.	Venture capital financing and the growth of high-tech start-ups: Disentangling treatment from selection effects.	2011	0	0	1	0	0	0	0	0	0	0	1	1
3	4	Piva et al.	The creation of high-tech entrepreneurial ventures at the local level: The role of local competences and communication infrastructures.	2011	1	0	0	0	0	0	0	0	1	0	0	1
4	5	Candi and Saemundsson	Exploring the Relationship Between Aesthetic Design as an Element of New Service Development and Performance.	2011	1	0	0	0	0	0	0	0	1	0	0	0
5	6	Taheri and Geenhuizen	How human capital and social networks may influence the patterns of international learning among academic spin-off firms.	2011	1	0	0	0	0	1	0	0	0	0	0	1
6	7	Ganotakis and Love	R&D, product innovation and exporting: Evidence from UK new technology based firms.	2011	0	0	1	0	0	1	0	0	0	0	1	1
7	8	Brinckmann et al.	Financial Management competence of founding teams and growth of new technology-based firms.	2011	1	0	0	0	0	1	0	0	0	0	1	1
8	9	Colombo and Grilli	On growth drivers of high -tech start-ups: Exploring the role of founders' human capital and venture capital.	2010	0	0	1	0	0	0	0	0	0	0	1	1
9	10	Bertoni et al.	Venture capital investments and patenting activity of high-tech start-ups: A micro-econometric firm level analysis.	2010	0	0	1	0	0	0	0	0	0	0	1	1
10	12	Bertoni et al.	The effect of venture capital financing on the sensitivity to cash flow of firm's investments.	2010	0	0	1	0	0	0	0	0	0	0	1	1
11	13	Robb and Coleman	Financing strategies of new technology-based firms: A comparison of women and men owned firms.	2010	1	0	0	0	0	0	0	0	0	0	0	1
12	15	Schillitoe and Chakrabarti	The role of incubator interactions in assisting new ventures.	2010	1	0	0	0	0	0	0	0	0	0	0	0
13	16	Gao et al.	The impact of initial conditions on new venture sucess: A longitudinal study of new technology-based firms.	2010	1	0	0	0	0	0	0	0	0	0	0	0
14	17	Colombo et al.	The contribution of university research to the growth of academic start-ups: An empirical analysis.	2010	0	0	1	0	0	0	0	0	0	0	1	1
15	18	Buganza et al.	Adoption of NPD flexibility practices in new technology-based firms.	2010	1	0	0	0	0	0	0	0	0	0	0	0
16	19	Maine et al.	The role of clustering in the growth of new technology-based firms.	2010	1	0	0	1	0	0	0	0	0	0	0	1
17	20	Campos et al.	Technology strategy and new technology based firms.	2010	1	0	0	0	1	0	0	0	0	0	0	1
18	24	Yang et al.	Are new technology-based firms on science parks really more innovative?	2009	0	0	0	0	0	0	0	0	0	0	0	1
19	26	West and Noel	The impact of knowledge resources on new venture performance.	2010	1	0	0	0	0	1	0	0	0	0	0	0
20	27	Candi and Saemundsson	Oil in water? Explaining differences in A«aesthetic design emphasis in new technology-based firms.	2009	1	0	0	0	0	1	0	0	1	0	0	0
21	29	Coeurderoy and Murray	Regulatory environments and the location decision: Evidence from the early foreign market entries of new technology-based firms.	2008	1	0	0	0	0	1	0	0	0	1	0	1
22	30	Minola and Giorgino	Who's going to provide the funding for high tech start-ups? A model for the analysis of determinants with a fuzzy approach.	2008	0	0	0	0	0	0	0	0	0	0	0	1
23	32	Colombo and Piva	Strenghs and weaknesses of academic startups: a conceptual model.	2008	1	0	0	0	0	0	0	0	0	0	1	1
24	35	Roskos and Klandt	Young technology ventures in Europe: Aspects of market orientation and entrepreneurial orientation.	2007	1	0	0	0	0	0	0	0	0	0	0	0
25	37	Colombo and Grilli	Funding gaps? Acess to bank loans by high-tech start-ups.	2007	0	0	1	0	0	1	0	0	0	0	1	1

N.º	INITIAL LIST	AUTHORS	MANUF._SECTOR	PHARMACOLOGY & PHARMACEUTICAL	COMPUTER	TELECOM. EQUIP.	ELECTRICAL & ELECTRONIC INDUSTRIES	MEDICAL/LASER & OPTICAL INSTRUMENTS	AEROSPACE	BIOTECH.	ICT	ROBOTICS & PROCESS AUTOMATION	NEW MATERIALS	CHEMISTRY	MECHANICS	FOOD & BEVERAGE	TEXTILE & CLOTHING	ENVIRONMENT & ENERGY	MICRO & NANO TECH	OTHER
1	2	Bianchi et al.	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2	3	Bertoni et al.	1	1	1	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0
3	4	Piva et al.	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0
4	5	Candi and Saemundsson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	6	Taheri and Geenhuizen	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0
6	7	Ganotakis and Love	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0
7	8	Brinckmann et al.	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	0
8	9	Colombo and Grilli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	10	Bertoni et al.	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
10	12	Bertoni et al.	1	1	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0
11	13	Robb and Coleman	1	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	1
12	15	Schillitoe and Chakrabarti	1	1	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0	0
13	16	Gao et al.	1	1	0	0	1	1	0	1	1	0	1	0	1	0	0	1	0	0
14	17	Colombo et al.	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0
15	18	Buganza et al.	1	1	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0
16	19	Maine et al.	1	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
17	20	Campos et al.	1	0	0	0	0	1	0	1	1	0	0	1	0	1	1	0	0	0
18	24	Yang et al.	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	26	West and Noel	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
20	27	Candi and Saemundsson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	29	Coeurderoy and Murray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	30	Minola and Giorgino	1	1	0	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0
23	32	Colombo and Piva	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
24	35	Roskos and Klandt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	37	Colombo and Grilli	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0

N.º	INITIAL LIST	AUTHORS	SERVICE_SECTOR	TELECOMMUNICATIONS SERVICES	ENGINEERING AND TECHNICAL TESTING	R&D	MULTIMEDIA	INTERNET BASED SERVICES	INFORMATION AND SOFTWARE	TECHNOLOGY CONSULTANCY	OTHER SERVICES	TOTAL SECTORS
1	2	Bianchi et al.	0	0	0	0	0	0	0	0	0	1
2	3	Bertoni et al.	1	0	0	0	1	1	1	0	0	11
3	4	Piva et al.	1	0	1	1	0	1	1	0	0	11
4	5	Candi and Saemundsson	1	1	1	1	0	0	1	0	1	5
5	6	Taheri and Geenhuizen	1	0	1	0	0	0	1	1	0	6
6	7	Ganotakis and Love	1	1	1	1	0	0	1	0	0	10
7	8	Brinckmann et al.	1	0	0	0	0	0	0	0	0	4
8	9	Colombo and Grilli	0	0	0	0	0	0	0	0	0	0
9	10	Bertoni et al.	1	0	0	0	1	1	1	0	0	12
10	12	Bertoni et al.	1	0	0	0	0	0	1	0	0	9
11	13	Robb and Coleman	1	0	1	0	0	0	1	0	0	11
12	15	Schillitoe and Chakrabarti	1	1	0	0	0	1	1	0	1	11
13	16	Gao et al.	0	0	0	0	0	0	0	0	0	8
14	17	Colombo et al.	1	1	0	0	0	1	1	0	0	8
15	18	Buganza et al.	1	1	0	0	0	1	1	0	0	8
16	19	Maine et al.	1	0	0	0	0	1	1	0	0	6
17	20	Campos et al.	0	0	0	0	0	0	0	0	0	6
18	24	Yang et al.	0	0	0	0	0	0	0	0	0	3
19	26	West and Noel	0	0	0	0	0	0	0	0	0	3
20	27	Candi and Saemundsson	0	0	0	0	0	0	0	0	0	0
21	29	Coeurderoy and Murray	0	0	0	0	0	0	0	0	0	0
22	30	Minola and Giorgino	1	0	0	0	0	1	1	0	0	8
23	32	Colombo and Piva	1	0	0	0	0	1	0	1	0	4
24	35	Roskos and Klandt	1	0	0	0	0	1	0	0	0	1
25	37	Colombo and Grilli	1	1	0	0	1	1	1	0	0	10

N.º	INITIAL LIST	AUTHORS	TITLE	DATE	NEW 1_10'	NEW_1_15'	NEW 1_25'	AVERAGE REVENUES	GROWTH RATE	SIZE SMALL	SIZE MEDIUM	SIZE LARGE	HUMAN CAPITAL DIMENSION	INDEPENDENT FIRMS	CAPITAL MAJORITY FTEAM	HIGH-TECH
26	39	Colombo et al.	In search of complementary assets: The determinants of alliance formation of high-tech start-ups.	2006	0	0	1	0	0	0	0	0	0	0	1	1
27	42	Aaboen et al.	Corporate governance and performance of small high-tech firms in Sweden.	2006	0	0	0	0	0	1	0	0	0	1	0	1
28	44	Lindelöf and Löbsten	Environmental hostility and firm behavior - An empirical examination of new technology-based firms in science parks	2006	0	0	0	0	0	0	0	0	0	1	0	1
29	47	Hogan and Hutson	The relation between key events in the development phase and the financial structure of NTBFs in the software sector	2006	0	0	1	0	0	1	0	0	0	1	0	1
30	48	Colombo and Grilli	Supporting high-tech start-ups: Lessons from Italian technology policy.	2006	0	0	1	0	0	0	0	0	0	0	1	1
31	50	O'Regan and Ghobadian	Innovation in NTBFs: Does leadership really matter?	2006	0	0	0	0	0	1	0	0	0	0	0	0
32	51	Studdard	The effectiveness of entrepreneurial firm's knowledge acquisition from a business incubator.	2006	0	0	0	0	0	0	0	0	0	0	0	1
33	53	Dettwiller et al.	Utility of location: a comparative survey between small new technology-based firms located on and of Science Parks - Implications for facilities management.	2006	1	0	0	0	0	1	0	0	0	1	0	1
34	54	Fukugawa	Science parks in Japan and their value-added contributions to new technology-based firms.	2006	0	0	0	0	0	0	0	0	0	1	0	1
35	56	Aspelung et al.	Initial resources' influence on new venture survival: a longitudinal study of new technology-based firms.	2005	0	1	0	0	0	0	0	0	0	1	0	0
36	57	Löbsten and Lindelöf	R&D networks and product innovation patterns - academic and non-academic new technology-based firms on Science Parks.	2005 b)	0	0	0	0	0	1	0	0	1	1	0	1
37	58	Colombo and Grilli	Founders' human capital and the growth of new technology-based firms: A competence-based view.	2005 b)	0	0	1	0	0	0	0	0	0	0	1	1
38	59	Kelley and Nakoesteen	Technology resources, alliances and sustained growth in new, Technology-Based Firms.	2005	1	0	0	0	0	0	0	0	0	0	0	1
39	60	Colombo and Grili	Start-up size: The role of external financing.	2005 a)	0	0	1	0	0	1	0	0	0	0	1	1
40	61	Löbsten and Lindelöf	Environmental hostility, strategic orientation and the importance of management accounting - an empirical analysis of new technology-based firms.	2005 a)	0	0	0	0	0	1	0	0	0	1	0	1
41	64	Coster and Butler	Assessment of proposals for new technology ventures in the UK: characteristics of university spin-off companies.	2005	0	0	0	0	0	0	0	0	0	0	0	1
42	65	Madill et al.	The role of angels in technology SMEs: A link to Venture Capital.	2005	1	0	0	0	0	0	1	0	0	0	0	0
43	66	Hogan and Hutson	Capital structure in new technology-based firms: Evidence from the Irish software sector.	2005	0	0	1	1	0	1	0	0	0	1	0	0
44	67	Lindelöf and Löbsten	Proximity as a Resource Base for Competitive Advantage: University–Industry Links for Technology Transfer.	2004	1	0	0	0	0	1	0	0	0	1	0	1
45	68	Lynskey	Knowledge, finance and human capital: the role of social institutional variables on entrepreneurship in Japan	2004	1	0	0	0	0	0	0	0	0	0	0	0
46	69	Colombo et al.	Entrepreneurs' human capital and the start-up size of new technology-based firms.	2004	0	0	1	0	0	1	0	0	0	0	1	1
47	71	Kollmer and Dowling	Licensing as a commercialisation strategy for new technology-based firms.	2004	1	0	0	1	0	0	1	0	0	0	0	0
48	72	Lindelöf and Löbsten	Science Park Location and New Technology-Based Firms in Sweden – Implications for Strategy and Performance.	2003	1	0	0	0	0	1	0	0	0	1	0	0
49	78	Dahlstrand and Jacobsson	Universities and Technology-based Entrepreneurship in the Gothenburg.	2003	0	0	1	0	0	0	0	0	1	1	0	1
50	79	Löbsten and Lindelöf	Determinants for an entrepreneurial milieu: Science Parks and business policy in growing firms.	2003	1	0	0	0	0	1	0	0	0	1	0	1

N.º	INITIAL LIST	AUTHORS	MANUF._SECTOR	PHARMACOLOGY & PHARMACEUTICAL	COMPUTER	TELECOM. EQUIP.	ELECTRICAL & ELECTRONIC INDUSTRIES	MEDICAL/LASER & OPTICAL INSTRUMENTS	AEROSPACE	BIOTECH.	ICT	ROBOTICS & PROCESS AUTOMATION	NEW MATERIALS	CHEMISTRY	MECHANICS	FOOD & BEVERAGE	TEXTILE & CLOTHING	ENVIRONMENT & ENERGY	MICRO & NANO TECH	OTHER
26	39	Colombo et al.	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
27	42	Aaboen et al.	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
28	44	Lindelöf and Löbsten	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
29	47	Hogan and Hutson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	48	Colombo and Grilli	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
31	50	O'Regan and Ghobadian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	51	Studdard	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
33	53	Dettwiller et al.	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
34	54	Fukugawa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	56	Aspelung et al.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	57	Löbsten and Lindelöf	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
37	58	Colombo and Grilli	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
38	59	Kelley and Nakoesteen	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	60	Colombo and Grili	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	61	Löbsten and Lindelöf	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
41	64	Coster and Butler	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0
42	65	Madill et al.	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	1
43	66	Hogan and Hutson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	67	Lindelöf and Löbsten	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
45	68	Lynskey	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
46	69	Colombo et al.	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
47	71	Kollmer and Dowling	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	72	Lindelöf and Löbsten	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
49	78	Dahlstrand and Jacobsson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	79	Löbsten and Lindelöf	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0

N.º	INITIAL LIST	AUTHORS	SERVICE_SECTOR	TELECOMMUNICATIONS SERVICES	ENGINEERING AND TECHNICAL TESTING	R&D	MULTIMEDIA	INTERNET BASED SERVICES	INFORMATION AND SOFTWARE	TECHNOLOGY CONSULTANCY	OTHER SERVICES	TOTAL SECTORS
26	39	Colombo et al.	1	1	0	0	1	1	1	0	0	10
27	42	Aaboen et al.	1	0	0	0	0	0	1	1	0	6
28	44	Lindelöf and Löbsten	1	0	0	0	0	0	1	1	0	6
29	47	Hogan and Hutson	1	0	0	0	0	0	1	0	0	1
30	48	Colombo and Grilli	1	1	0	0	1	1	1	0	0	10
31	50	O'Regan and Ghobadian	0	0	0	0	0	0	0	0	0	0
32	51	Studdard	1	0	0	0	0	1	0	0	0	4
33	53	Dettwiller et al.	1	0	0	0	0	0	1	1	0	6
34	54	Fukugawa	0	0	0	0	0	0	0	0	0	0
35	56	Aspelung et al.	0	0	0	0	0	0	0	0	0	0
36	57	Löbsten and Lindelöf	1	0	0	0	0	0	1	1	0	6
37	58	Colombo and Grilli	1	1	0	0	1	1	1	0	0	10
38	59	Kelley and Nakoesteen	0	0	0	0	0	0	0	0	0	2
39	60	Colombo and Grilli	0	0	0	0	0	0	0	0	0	0
40	61	Löbsten and Lindelöf	1	0	0	0	0	0	1	1	0	6
41	64	Coster and Butler	1	0	0	0	0	0	1	0	0	4
42	65	Madill et al.	1	1	0	0	0	1	1	0	0	10
43	66	Hogan and Hutson	1	0	0	0	0	0	1	0	0	1
44	67	Lindelöf and Löbsten	1	0	0	0	0	0	1	1	0	6
45	68	Lynskey	0	0	0	0	0	0	0	0	0	2
46	69	Colombo et al.	1	1	0	0	1	1	1	0	0	10
47	71	Kollmer and Dowling	0	0	0	0	0	0	0	0	0	1
48	72	Lindelöf and Löbsten	1	0	0	0	0	0	1	1	0	6
49	78	Dahlstrand and Jacobsson	0	0	0	0	0	0	0	0	0	0
50	79	Löbsten and Lindelöf	1	0	0	0	0	0	1	1	0	6

N.º	INITIAL LIST	AUTHORS	TITLE	DATE	NEW 1_10'	NEW_1_15'	NEW 1_25'	AVERAGE REVENUES	GROWTH RATE	SIZE SMALL	SIZE MEDIUM	SIZE LARGE	HUMAN CAPITAL DIMENSION	INDEPENDENT FIRMS	CAPITAL MAJORITY FTEAM	HIGH-TECH
51	80	Löbsten	Science Parks and the growth of new technology-based firms - academic-industry links, innovation and markets.	2002	1	0	0	0	0	1	0	0	0	1	0	1
52	82	Colombo and Delmastro	How effective are technology incubators? Evidence from Italy	2002	0	0	1	0	0	0	0	0	0	1	0	1
53	83	Kelley and Rice	Leveraging the Value of Proprietary Technologies	2002	0	1	0	0	0	0	0	0	0	1	0	1
54	84	Lindelöf and Löbsten	Growth, management and financing of new technology-based firms—assessing value-added contributions of firms located on and off Science Parks	2002	1	0	0	0	0	1	0	0	0	1	0	1
55	85	Yli-Renko et al.	The role of contractual governance flexibility in realizing the outcomes of key customer relationships.	2001	1	0	0	0	0	1	0	0	0	1	0	1
56	86	Löbsten and Lindelöf	Science parks in Sweden: Industrial renewal and development?	2001	1	0	0	0	0	1	0	0	0	1	0	1
57	87	Igel and Islam	Strategies for service and market development of entrepreneurial software designing firms.	2001	1	0	0	0	0	0	0	0	0	0	1	1
58	88	Fontes and Coombs	Contribution of new technology-based firms to the strengthening of technological capabilities in intermediate economies.	2001	0	1	0	0	0	0	0	0	0	0	1	0
59	91	Druilhe and Garnsey	Emergence and growth of high-tech activity in Cambridge and Grenoble	2000	0	0	0	0	0	1	0	0	0	0	0	1
60	93	Almus and Nerlinger	Growth of New Technology-Based Firms: Which Factors Matter?	1999	1	0	0	0	0	1	0	0	0	1	0	1
61	95	Pfirrmann	Neither soft nor hard — pattern of development of new technology based firms in biotechnology.	1999	0	1	0	0	0	1	0	0	0	1	0	1
62	96	Chorda and Perales	A new tool to classifying new technology-based firm: prospects and expectations.	1999	1	0	0	0	0	1	0	0	0	0	0	1
63	99	Autio and Parhankangas	Employment Generation Potential of New, Technology-Based Firms during a recessionary period: The Case of Finland.	1998	1	0	0	0	0	1	0	0	0	0	0	1
64	100	Yli-Renko and Autio	The Network Embeddedness of New, Technology-Based Firms: Developing a systemic evolution model.	1999	1	0	0	0	0	1	0	0	1	1	0	0
65	101	Autio and Yli-Renko	New, technology-based firms as agents of technological rejuvenation.	1998 b)	1	0	0	1	0	1	0	0	0	1	0	0
66	102	Autio and Lumme	Does the innovator role affect the perceived potential for growth? Analysis of four types of new technology-based firms.	1998	1	0	0	1	0	1	0	0	0	1	0	0
67	105	Autio and Yli-Renko	New, technology-based firms in small open economies - An analysis based on the Finnish experience.	1998 a)	1	0	0	1	0	1	0	0	0	1	0	1
68	109	Laranja and Fontes	Creative adaptation: The role of new technology based firms in Portugal.	1998	1	1	0	0	0	1	0	0	1	0	1	0
69	114	Dalhstrand	Entrepreneurial spin-off enterprises in Göteborg, Sweden.	1997	0	0	1	0	0	1	0	0	0	0	0	0
70	116	Autio	New, technology-based firms in innovation networks symplectic and generative impacts.	1997	1	0	0	1	0	1	0	0	1	0	0	0
71	117	Reitan	Fostering technical entrepreneurship in research communities: granting scholarships to would-be entrepreneurs.	1997	1	0	0	0	0	1	0	0	0	0	0	0
72	122	Fontes and Coombs	New technology-based firms and technology acquisition in Portugal: Firms' adaptive responses to a less favourable environment	1995	0	1	0	0	0	0	0	0	0	0	1	0
73	126	Segers	Strategic Partnering between New Technology Based Firms and Large Established Firms in the Biotechnology and Micro-electronics Industries in Belgium.	1993	1	0	0	0	0	0	0	1	0	0	0	0
74	127	Sternberg	The Impact of Innovation Centres on Small Technology-Based Firms: The Example of the Federal Republic of Germany.	1990	1	0	0	0	0	1	0	0	0	0	0	0
75	128	Donckels and Segers	New Technology Based Firms and the creation of regional growth potential - Theorical considerations and empirical evidence for Belgium.	1990	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL					41	6	17	7	1	37	2	2	9	26	18	48

N.º	INITIAL LIST	AUTHORS	MANUF._SECTOR	PHARMACOLOGY & PHARMACEUTICAL	COMPUTER	TELECOM. EQUIP.	ELECTRICAL & ELECTRONIC INDUSTRIES	MEDICAL/LASER & OPTICAL INSTRUMENTS	AEROSPACE	BIOTECH.	ICT	ROBOTICS & PROCESS AUTOMATION	NEW MATERIALS	CHEMISTRY	MECHANICS	FOOD & BEVERAGE	TEXTILE & CLOTHING	ENVIRONMENT & ENERGY	MICRO & NANO TECH	OTHER
51	80	Löbsten	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
52	82	Colombo and Delmastro	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
53	83	Kelley and Rice	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	84	Lindelöf and Löbsten	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
55	85	Yli-Renko et al.	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0
56	86	Löbsten and Lindelöf	1	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
57	87	Igel and Islam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	88	Fontes and Coombs	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
59	91	Druilhe and Garnsey	1	0	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0
60	93	Almus and Nerlinger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	95	Pfirrmann	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
62	96	Chorda and Perales	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
63	99	Autio and Parhankangas	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0
64	100	Yli-Renko and Autio	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	1	0	0
65	101	Autio and Yli-Renko	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
66	102	Autio and Lumme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	105	Autio and Yli-Renko	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	109	Laranja and Fontes	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
69	114	Dalhstrand	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
70	116	Autio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	117	Reitan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	122	Fontes and Coombs	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
73	126	Segers	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
74	127	Sternberg	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1
75	128	Donckels and Segers	1	0	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0	0
TOTAL			56	32	21	18	41	22	10	28	14	13	9	17	15	1	1	5	3	3

N.º	INITIAL LIST	AUTHORS	SERVICE_SECTOR	TELECOMMUNICATIONS SERVICES	ENGINEERING AND TECHNICAL TESTING	R&D	MULTIMEDIA	INTERNET BASED SERVICES	INFORMATION AND SOFTWARE	TECHNOLOGY CONSULTANCY	OTHER SERVICES	TOTAL SECTORS
51	80	Löbsten	1	0	0	0	0	0	1	1	0	6
52	82	Colombo and Delmastro	1	0	0	0	1	1	1	0	0	8
53	83	Kelley and Rice	1	0	0	0	0	0	0	0	0	2
54	84	Lindelöf and Löbsten	1	0	0	0	0	0	1	1	0	6
55	85	Yli-Renko et al.	0	0	0	0	0	0	0	0	0	5
56	86	Löbsten and Lindelöf	1	0	0	0	0	0	1	1	0	6
57	87	Igel and Islam	1	0	0	0	0	0	1	0	0	1
58	88	Fontes and Coombs	1	0	0	0	0	0	1	0	0	5
59	91	Druilhe and Garnsey	1	0	1	1	0	0	1	0	1	11
60	93	Almus and Nerlinger	0	0	0	0	0	0	0	0	0	0
61	95	Pfirrmann	0	0	0	0	0	0	0	0	0	1
62	96	Chorda and Perales	1	0	0	0	0	0	1	0	1	3
63	99	Autio and Parhankangas	1	1	1	0	0	0	1	1	0	10
64	100	Yli-Renko and Autio	0	0	0	0	0	0	0	0	0	5
65	101	Autio and Yli-Renko	1	1	0	0	0	0	1	0	1	5
66	102	Autio and Lumme	0	0	0	0	0	0	0	0	0	0
67	105	Autio and Yli-Renko	0	0	0	0	0	0	0	0	0	0
68	109	Laranja and Fontes	1	0	0	1	0	0	1	1	1	5
69	114	Dalhstrand	1	0	0	0	0	0	1	1	0	6
70	116	Autio	0	0	0	0	0	0	0	0	0	0
71	117	Reitan	0	0	0	0	0	0	0	0	0	0
72	122	Fontes and Coombs	0	0	0	0	0	0	0	0	0	1
73	126	Segers	0	0	0	0	0	0	0	0	0	3
74	127	Sternberg	0	0	0	0	0	0	0	0	0	4
75	128	Donckels and Segers	0	0	0	0	0	0	0	0	0	6
TOTAL			47	13	7	5	8	18	42	16	6	368

Annex 2: Questionnaire

This survey is part of an investigation realized by *Faculdade de Economia do Porto* - UP researchers, which has as target the firms incubated in the UPTEC Centers. The information collected will be used exclusively for academic purposes, being guaranteed the confidentiality of data and their aggregated treatment.

A) COMPANY DATA

A.1. Date of establishment _____ (dd/mm/yyyy)

A.2. Amount of capital

At the constitution date _____ In 31/Dec/2010 _____

Capital distribution at the constitution date: Capital distribution in 31/Dec/2010 (if different from the initial one):

Founding Team	Partner Type			% Constitution Date	Founding Team	Partner Type			% 31/Dec/2010
	Company	Individual	Other (Specify)			Company	Individual	Other (Specify)	
Partner 1	☐	☐			Partner 1	☐	☐		
Partner 2	☐	☐			Partner 2	☐	☐		
Partner 3	☐	☐			Partner 3	☐	☐		
Partner 4	☐	☐			Partner 4	☐	☐		
Partner 5	☐	☐			Partner 5	☐	☐		
(.....)	☐	☐			(.....)	☐	☐		

Note - For each partner select the partner type and % in the firm Capital.

A.3. N.º of founding members:

At the constitution date N.º partners in 31/Dec/2010 _____

N.º of partners with performance of Capital _____ How many were founders? _____

N.º of partners with performance of Work _____

A.4. N.º of employees (behind the partners):

At the constitution date _____ In 31/Dez/2010 _____

Undergraduate or higher _____ Undergraduate or higher _____

A.5. Main activity in the firm

Product ☐ Service ☐ Product and Service ☐

A.6. Financial data

First Year of sales _____

Sales in the 1.st year (€ thousands) _____ Sales in 31/Dec/2010 (€ thousands) _____

R&D Expenses (€ thousands)

In the 1.st year of sales (until 31/Dec) _____ In 31/Dec/2010 _____

Share of exports (% of Sales)

In the 1.st year of sales _____ In 31/Dec/2010 _____

N.º of patents assigned

At the constitution date _____ In 31/Dec/2010 _____

Geographical space of the patent: National ☐

European ☐

Other(s) ☐ Specify: _____

N.º of patents in registration phase

At the constitution date _____ In 31/Dec/2010 _____

Geographical space of the registration: National ☐

European ☐

Other(s) ☐ Specify: _____

B) CHARACTERIZATION OF THE FOUNDING TEAM

TEAM	*Qualifications*					*Scientific Area*				
	Less than Undergraduate	Undergraduate	Master	Phd	*Other (Specify)*	*Engineering and related areas*	*Life Sciences*	*Computer Science*	*Business Sciences*	*Other (Specify)*
Partner 1	☐	☐	☐	☐		☐	☐	☐	☐	
Partner 2	☐	☐	☐	☐		☐	☐	☐	☐	
Partner 3	☐	☐	☐	☐		☐	☐	☐	☐	
Partner 4	☐	☐	☐	☐		☐	☐	☐	☐	
Partner 5	☐	☐	☐	☐		☐	☐	☐	☐	
(.....)	☐	☐	☐	☐		☐	☐	☐	☐	

Note - In case of undergraduate or higher qualification, please select the scientific area. The classification must be done for each partner, with an "X".

C) RESOURCES BROUGHT BY EACH MEMBER IN THE FOUNDING TEAM TO THE FIRM

TEAM	Capital	Network of business contacts	Knowledge of the business	Patents	Other (Specify)
Partner 1	☐	☐	☐	☐	
Partner 2	☐	☐	☐	☐	
Partner 3	☐	☐	☐	☐	
Partner 4	☐	☐	☐	☐	
Partner 5	☐	☐	☐	☐	
(.....)	☐	☐	☐	☐	

Note - Select to each partner the answer (or answers), with an "X".

To partners with professional experience, specify the number of years:

TEAM	Professional Experience Nº of years		Nº of years in the firm activity	
Partner 1				
Partner 2				
Partner 3				
Partner 4				
Partner 5				
(.....)				

Note - The reference is the constitution date.

D) SOURCE OF THE TECHNOLOGY/ KNOWLEDGE

Product/Service	Process of Technology Transfer			Internal	Acquisition		Other
	University Department	Research Centre	In Consortium	Development	National	Import	(Specify)
Source	☐	☐	☐	☐	☐	☐	

For any additional information please contact Dina Cunha by phone (964238863) or e-mail (ASOUP@fep.up.pt).

Thank you.